HAND-BOOK

OF

CYCLONIC STORMS IN THE BAY OF BENGAL.

FOR THE USE OF SAILORS.

BY
JOHN ELIOT, M.A.,
METEOROLOGICAL REPORTER TO THE GOVERNMENT OF INDIA.

Published by the Meteorological Department of the Government of India.

CALCUTTA:
PRINTED BY THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.
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PREFACE.

THIS work has been prepared for the information and guidance of sailors navigating the Bay of Bengal. It gives all the more important facts and results of the information that has been collected by the Calcutta Meteorological Office during the past twenty years, chiefly from sailors, respecting storms in the Bay of Bengal. It hence represents what may be termed the present working capital of that office used in its work of forecasting storms. The author has endeavoured to give the facts and results without any reference or bias to any particular theory of cyclone generation and motion. He has also made the rules for the practical guidance of sailors as precise and definite as possible. A vague rule, more especially, if intended for action in time of danger, is almost as unsatisfactory as no rule at all. It has, however, been carefully pointed out to what extent and from what causes the rules and indications given for guidance are likely, so far as can be judged, to fail. The author has also endeavoured to point out in what directions sailors can assist in taking weather observations in the Bay of Bengal with a view to assist in improving our knowledge of the laws of storms as applicable to that area. There are several rival theories of cyclone formations and motion in the field, and it is only by the collection and examination of more and more exact observations made by persons who take a keen and intelligent interest in the subject that it will be possible to test these theories and to select finally a correct and adequate theory.

Hence, whilst one object of the work is to give sailors a full statement and explanation of what must be called "the laws of storms in the Bay of Bengal" for their practical guidance, another is to induce sailors to observe accurately and fully the weather in the Bay of Bengal in the hope that they will send in copies of their observations to the Calcutta Meteorological Office, where they would be carefully considered and every fact likely to be of practical or theoretical use carefully noted and recorded.

The subject is even yet in its infancy, and the present work is for that and other reasons confessedly imperfect. It is to be feared there

are many mistakes in the book, although every effort has been taken in the enumeration of the very large amount of information which has been accumulated in the Calcutta Meteorological Office, and in drawing up the various tables and charts to ensure accuracy. The author will be grateful to any one pointing out errors of any kind and more especially to Captains acquainted with the weather and other conditions of the Bay of Bengal who will give him at any time information for, or against, any of the inferences, indications, or rules stated in the book for guidance in forecasting or ascertaining the position, track or intensity of storms in the Bay. Any information of this kind, sent in to the Meteorological Reporter, Meteorological Office, Calcutta, will receive the fullest consideration and be utilized in the preparation of the next edition of the work, which it is proposed to issue if it is found that the present is of practical value to sailors navigating the Bay of Bengal.

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HAND-BOOK

OF

CYCLONIC STORMS IN THE BAY OF BENGAL

FOR

THE USE OF SAILORS.

INTRODUCTION.

THE chief object of this little volume is to give the mariner who navigates the Bay of Bengal an account of the dangerous storms that occur in it, to state and explain the signs and indications by which he may recognize when he is approaching a cyclone, or that a cyclone is forming in that part of the Bay which he is traversing, and to furnish him with information and methods by which he may ascertain sufficiently for all practical purposes the bearing or direction of the storm centre, and of the path of any cyclonic storm he may meet with in the Bay.

By following these or similar instructions he will, in the great majority of cases, if not in all, when he is involved in cyclonic weather in the Bay of Bengal, be enabled to avoid the inner storm area of dangerous winds, and fierce squalls and rapid shift of wind.

It is hardly necessary to remind sailors that the storms which are met with in the Bay of Bengal are occasionally of excessive violence. Formerly, when little or nothing was known of the laws of storms, they caused frequent grave destruction to shipping. The following brief accounts of two cyclonic storms which occurred in the Bay of Bengal 150 years ago, extracted from Orme's History of India, will enable the reader to realize the dangers which sailors occasionally encountered in former days in the Bay of Bengal:—

"On the 2nd of October 1746 the weather at Madras was remarkably fine and moderate all day. About midnight a furious storm arose, and continued with the greatest violence until the noon of the next day. Six of the French ships were in the road when the storm began, and not one of them was seen at daybreak. One put before the wind and was driven so much to the southward that she was not able to gain the coast again; the 70-gun ship lost all her masts; three others of the squadron were likewise dismasted, and had so much water in the hold that the people on board expected every minute to perish, notwithstanding they had thrown overboard all the cannon of the lower tier; the other ship, during the few moments of the whirlwind, which happened in the most furious part of the storm, was covered by the waves, and foundered in an instant, and only six of the crew escaped alive. Twenty other vessels, belonging to different nations, were either driven on shore or perished at sea. Two ships, laden

with part of the effects of Madras, together with three lately arrived from Europe, were at anchor in the road of Pondicherry, where they felt no effect of the storm which was raging at Madras.

"In the evening of the 13th of April 1749 the northern monsoon changed, and the southern commenced with a hurricane on the Coromandel Coast. At Portonovo it lasted with such violence until four o'clock the next morning that the tents of the English forces which were encamped on the bank of the River Valaru (which disembogues itself at Portonovo, were blown into rags, many of the draught bullocks and horses were killed, and all the military stores were so much damaged that the army was obliged to march to Portonovo, in order to repair the detriments it had sustained. Here they were informed that the storm had committed much greater ravages at sea; two of the Company's ships were stranded between Cuddalore and Fort Saint David; the *Apollo* hospital ship was lost with all her crew; the *Pembroke*, a 60-gun ship, which sailed on the expedition, was wrecked and only six of the crew saved; and the *Hamur* of 74 guns, in which Admiral Boscawen hoisted his flag, and which was the finest ship of her size belonging to the navy of England, perished with 750 men. Fortunately most of the other ships were either at Trincomalee, or in parts of the coast to which the greatest violence of the hurricane did not extend."

It is hardly too much to say that the knowledge of the laws of storms, which is due to the labours of meteorologists utilizing the observations furnished by thousands of seamen, is now sufficient, if properly employed, to enable sailors to avoid the full strength of cyclonic storms in the open sea of the Bay of Bengal. Disasters still occasionally happen, and, in some cases at least, may be traced to neglect of the most ordinary precautions, or to disregard of the accumulated experience of the past. The following are the most noteworthy disasters which have occurred in the Indian seas during the past four years. During a cyclonic storm in the Arabian Sea and Gulf of Aden in May 1885, the *Augusta* German man-of-war, the *Renard* French man-of-war, and the S. S. *Speke Hall* foundered at sea, within a few hours of each other. In May 1887 the Steamer *Sir John Lawrence*, with upwards of 800 pilgrims for Pooree on board, foundered in a cyclonic storm on her passage from Calcutta to Chandbally. In June 1887 the steamer *Lamport* left Bombay Harbour during stormy weather in the Arabian Sea and foundered at sea. Finally, in November 1888 the coasting steamer *Vaitarna*, with several hundreds of native passengers, went down off the coast of Kattiawar during a cyclonic storm in the Arabian Sea.

These examples are sufficient to show that well-appointed steamers and local steamers under the command of masters who had many years' experience of the storms of the seas they were navigating have foundered during recent cyclonic storms in the Indian seas. The dangers are hence as great and real now as they were a hundred and fifty years ago, when much less was known of their character, and it is only by the exercise of prudent caution and the employment of the accumulated experience of the past formulated in what is now commonly called "the laws of storms" that sailors will be able to avoid the worst dangers of these storms. The chief object of this work is hence to state the laws of the formation, course, and character of storms in the Bay of Bengal, so far as they are at present known, mainly from observations furnished by sailors.

Arrangement of subjects.—The subject is treated under the following heads:—

(1) Explanation of meteorological ideas and phrases and of some of the more important principles of the science.

(2) Description of the chief phenomena of cyclonic storms in the Bay of Bengal, and explanation of methods of ascertaining the existence, position and course of cyclonic storms.

(3) Brief account of six of the most important and typical storms in the Bay of Bengal during the past 25 years.

(4) Summary, giving brief practical hints respecting storms for the use of sailors navigating the Bay of Bengal.

CHAPTER I.

EXPLANATION OF METEOROLOGICAL PHRASES AND PRINCIPLES.

Before commencing the subject of this volume, *viz.* cyclones, it appears to be desirable to give a brief explanation of those properties of air which are of importance in meteorology, and of the chief technical terms made use of by all who study the weather at the present time, and also of some of the more important results of meteorological observation in India and the adjacent seas.

Necessity of technical terms.—No class of men know better than sailors the necessity and value of technical language, as they employ it perhaps to a larger extent than any other class of men. The following extracts from a very interesting work called "Sailors' Language," by Clark Russell, state this in a very striking manner: "Sailors' talk is a dialect as distinct from ordinary English as Hindustani is, or Chinese. English words are used, but their signification is utterly remote from the meaning they have in shore parlance. A yard ashore means a bit of ground at the back of a house; at sea it is a spar. Every cabman knows what a whip is; but at sea it is a tackle formed by a single rope rove through a block. A traveller ashore is a well-known individual; but at sea he becomes an iron ring fitted so as to slip up and down a rope. A lizard is not a reptile, but a bit of rope with an iron thimble spliced into it, just as a bull is a small keg, and bees pieces of plank at the outer end of the bowsprit. Beating is not striking, but sailing by tacks; a bonnet is not for ladies' wear, but a piece of canvas laced to the foot of a jib; whilst a cat's-paw has as little to do with the feline animal as fiddles and harpings have with music." And "of many sea-phrases the meaning is really so subtle as utterly to defy translation, whilst many fit the vocational conditions so accurately that any divergence from the exact expression will puzzle a seaman as much as if he was being ordered about in French. There are shades of signification in the terms which a man must go to sea as a sailor to understand. No books will give them. They are not to be mastered by listening to seamen talking." "Any way, it is quite certain that to stop a sailor from telling his story in his own fashion is, to use his phrase, 'to bring him up with a round turn,' and to expect him to find other words than those which occur naturally to him in relating incidents of a profession crowded with expressions to be heard nowhere except on board ship, is to put him upon a labour of definitions which even a Samuel Johnson would, I suspect, very promptly decline."

Hence sailors at least will excuse, even if they do not always appreciate, the two or three dozen technical terms such as *inertia*, *baric gradient*, *humidity*, &c., which meteorologists use for the sake of brevity and clearness. Technical language has the great advantage of being perfectly clear and definite to those who understand it. It is generally a little troublesome to acquire, but no one who has learnt it ever thinks of returning to the clumsy roundabout expressions which it replaced. Meteorologists have been obliged to employ a number of technical terms and expressions, and it is very desirable, if not absolutely necessary, that every one who wishes to make use of weather reports or publications

issued by Meteorological offices should learn to understand those terms. It is therefore proposed in this chapter to describe some of the chief properties of the air or atmosphere surrounding the earth, and also to explain the more important terms used by meteorologists in describing and explaining the weather, and more especially storms.

Air has weight.—The air is an invisible substance, very light as compared with the same volume of ordinary solid matter, but, notwithstanding, having weight. This is of course very easily proved by weighing accurately a hollow stoppered bottle or vessel, first with air inside, and, secondly, after the air has been pumped out by means of an air-pump. There is always found a slight difference between the two weighings, the difference representing the weight of the air which was inside the vessel in the first case.

The weight of any number of cubic feet of a gas or of air can be at once found by a simple multiplication sum when the weight of one cubic foot is known.

The chief difference between liquids and solids on the one hand and gases on the other is that while a cubic foot of a liquid or solid weighs practically the same under all ordinary circumstances, the weight of a cubic foot of air differs very greatly under different circumstances and may be as small a quantity as ever we please. This is due to the fact that gases possess the property of indefinite expansion as their pressure diminishes.

Method of calculating the weight of a quantity of air.—The weight of a cubic foot of dry air at rest near the earth's surface depends really upon two factors—its temperature and the amount of pressure to which it is subject. It is very rarely necessary in meteorology to know the weight in pounds or ounces of a cubic foot of air, but the following rules will enable any one to find it approximately in any given case.

The weight of a cubic foot of air at the pressure of 30 inches (that is, when the upper surface of the column of mercury in the tube of a barometer placed in the air stands at a height of 30 inches above the level of the mercury in the cistern), and at the temperature of freezing water (or 32° Fahr.) is 565 grains or 1·29 ounces. 7,000 grains, it should be remembered, are exactly equivalent to one pound. If the air be kept at the same pressure (by allowing it to expand suitably), every degree rise of temperature diminishes the weight of a cubic foot by one grain very approximately. Thus, the weight of a cubic foot of air near the surface of the sea in the Bay of Bengal, when the barometer stands at 30·00 inches, and the temperature is 72° (or 40° higher than the freezing point), is 565 less 40, or 525 grains. When the weight of a cubic foot of air at the pressure 30 inches and at any temperature has been found, the weight of a cubic foot at any other pressure at the same temperature, can be at once found by a rule-of-three sum, the principle being that the weight diminishes at the same rate as the pressure decreases. Thus, if the pressure diminishes from 30 inches to 29 inches or one inch out of 30, the weight will also diminish by $\frac{1}{30}$th, and so on. Thus, in the centre of the False Point Cyclone of September 1885, where the air was at the temperature 82° and the barometer stood at 27 inches nearly (or more exactly 27·13"), the weight of a cubic foot of air was only 464 grains, or 100 grains less than the weight of a cubic foot of air on a dry cold winter day in England. This follows at once from what has been said. The weight of a

cubic foot of air at 30 inches pressure and temperature 82° (or 50° above the freezing point) is 565 grains less 50 grains, or 515 grains, and at 27 inches pressure, or 3 inches less than 30 inches (that is, a decrease of 1 in 10), the weight would be 515 less 51·5 grains (because 51·5 is the tenth part of 515), or 463·5 grains.[1]

Air has inertia.—The fact that the air is a heavy substance is one of much importance to the meteorologist from another point of view. If it be wished that a heavy body should move from rest or move more quickly, force must be applied to it, or work must be done upon it by some agent. Also, when a heavy body is in motion there are always resistances which oppose its motion, and tend to bring it to rest. Hence, if its motion is to continue unaltered for a considerable interval of time, work must be done upon it or energy given to it by some agent or other portion of matter. The principles of work and energy appear to be more or less mysterious when stated in mathematical form. They are however comparatively simple, and are more or less fully acted on by every workman. Any sailor wishing to have a simple statement and explanation with numerous illustrations from every-day life is recommended to read Balfour Stewart's "Conservation of Energy." It will suffice to give one or two illustrations. A mason every time he lifts a hammer does work on the hammer, and at the same time he loses a small amount of energy, *i.e.* that something which he possesses to a limited amount, and in virtue of which he can do a certain amount of work. The hammer when lifted up, although unchanged in appearance, has acquired some energy or power of doing work, and this is shown by the fact that if it be allowed to fall down on a piece of iron or stone, it will make some change in it. If properly directed during its fall by the workman, it will effect the change required, *e.g.*, break off the exact portion of stone desired or hence do useful work. If it be improperly directed, it will still fall and do work *e.g.*, break off a portion of the stone, but it will probably not be useful work, *i.e.* that which will be of use for the particular object the workman has in view. Similar principles apply in any other of the numberless cases which will occur to any one.

Work may perhaps be best defined as *the exercise of force by some portion of matter through a definite space in order to produce a change of the position, shape or motion of some other portion of matter. Energy is that property of matter by which it is enabled to do work of any kind.*

The principles of work and energy apply equally to the motion, &c., of matter in the gaseous form as to that of matter in the solid state. This is, from one point of view, usually expressed by stating that air, like solid or liquid masses of matter, has the property of inertia, that is, requires force (due to the action on it of some other mass of matter) to put it in motion, to maintain its motion unaltered against resistance, or to bring it to rest when in a state of motion. Exactly the same principles and the same methods of argument, for example,

[1] For any who can use a simple mathematical formula the weight of a cubic foot of air can be calculated approximately at ordinary temperatures from—

$$W = \frac{19p}{1 + \frac{t}{500}} = 19p\left(1 - \frac{t}{500}\right)$$

Where W is the weight in grains (of which 7,000 make a pound avoirdupois), p the pressure measured in inches of barometric height, and t the temperature above the freezing point in degrees Fahrenheit.

hold good for the motion of a mass of air as for the motion of a steamer or of a railway train. Coal, for example, is the agent in these cases. It contains before it is burnt a large amount of energy, which with proper arrangements it can give out to the mechanism of the steamer or train and the attached bodies. When the machinery begins to act, it causes the ship or train to move more quickly up to a certain limit. If its action be discontinued (*i.e.* the steam be shut off from the engine), the steamer or train comes gradually to rest as its motion is resisted by the air, by friction with the water or rails, &c. If it be required to move at the same rate for some time, the engines must continue to be worked, for, if not, the body will gradually move more and more slowly and finally come to rest. One of the simplest, and yet most important, considerations for an engineer of a steamer, &c., is that the engines should be powerful enough to move the steamer, &c., at the average rate (10 or 12 miles per hour) that is desired. It would be an absurd act of folly that no one would think of committing to put engines intended for a small steam yacht into a 6,000-ton man-of-war steamer.

The sun is the great source of energy or the motive power acting directly or indirectly on the atmosphere.—It has been already stated that the air is like any other kind of matter, as, for example, a railway train, a cannon ball, or a piece of machinery, in that if it is at rest it cannot put itself in motion, or if moving it cannot of itself move more quickly, or if moving as it does in the open against resistances, work must be done upon it or energy communicated to it by some other portion of matter if it continues to move with undiminished velocity. Any change of motion of a mass of air can only be effected by some power or force (due to some other portion of matter) acting on it. This power or force may either act directly or indirectly through some connection (equivalent to a train of mechanism) transmitting the moving power or acting force. Hence one of the more important enquiries that any one studying the weather has to take up, is to find out what is the agent or motive power which supplies the energy that puts large masses of air into rapid motion and maintains the motion for considerable intervals of time. For example, in many of the larger cyclones of the Bay, a mass of air, 100 miles at least in diameter and probably not less than a mile in height, is caused to move at a rate which averages at least 40 (if not 60) miles per hour. The mass of air put into this rapid motion weighs as much as half a million 6,000-ton ships at the least and moves more than three times as quickly. It should also be remembered that this amount of motion has not only to be gradually given to the mass of air, but that it is frequently continued for several days against the various resistances offered to the moving mass of air. How effective and powerful these resistances may be in certain cases is shown by the fact that the Backergunj cyclone, one of the largest of the present century, was completely destroyed by the resistance of the hills of Eastern Bengal in the space of a few hours. The amount of power necessary to maintain this motion after it has been generated is difficult to estimate, but is certainly equal to the engine power that would be necessary to drive some hundreds of thousands of 6,000-ton steamers at the rate of 12 miles per hour. Whence is this power, this energy, derived? It is in trying to answer this question that many make the mistake of assigning an utterly inadequate and feeble cause to a vast and massive effect or result. Some, for ex-

ample, suggest the electricity of thunder-storms, &c. It can, however, be shown, and has been proved conclusively, by Faraday and others, that the electricity set free in a violent thunder-storm would not have sufficient energy or power to drive an electrical tram-car half a mile, or produce more violent effects than a few pounds of dynamite. Others again believe that the moon is mainly responsible for the violent motion of large masses of air which form storms, and that when its illuminated face is turned full, or sideways, or in some other particular direction, it is much more powerful and influential than at other times.

The force of the sun upon the whole earth or upon any body or mass of matter of any kind at or near the earth's surface is 140 times as great as that of the moon on the same body. The common statement that the earth moves round the sun and not round the moon is the ordinary and less definite way of expressing the same fact. Hence, under similar circumstances, the sun will be able to do by its mere pull, or attracting force, on the earth or any mass connected with the earth through a given distance 140 times as much work or produce 140 times as great an effect as the moon.

This statement, it may perhaps be desirable to add, is quite compatible with the fact that the tide-producing power of the moon on the oceanic waters of the earth is considerably greater than that of the sun. The tides, it may be sufficient to state, are due to the fact that the moon and sun attract the waters of the earth at different portions of its surface with different amounts of force according as these portions are nearer or further away. It is hence quite easy to see generally that a moderate-sized body like the moon at a comparatively small distance may produce a greater difference of effects at different parts of the earth than the larger body, the sun, which is at a very much greater distance. For a similar reason a bar magnet placed at a small distance from a magnetic needle tends to pull it away as well as to turn it round, whilst the earth, an immense magnetic body, exercises practically no pull on the magnetic needle, though it turns it or directs it into a certain fixed position.

There is a second way in which the sun is exceedingly more effective and powerful than the moon.

The sun is an enormous reservoir of heat which it is giving out continuously. The heat thus radiated is propagated through space, and produces at the surfaces and in the atmospheres of the planets all the changes that heat is capable of effecting. The moon on the other hand is a cold body which scatters a little of the heat it receives from the sun into space. This is however so small in amount that the most delicate instruments are required to measure it.

The following results of calculation will perhaps put the matter more strongly and clearly. The amount of the sun's heat received by the moon is only about one thirty thousand millionth part ($\frac{1}{30,000,000,000}$) of the whole heat given out by the sun. Hence, as a centre of communicating heat, (assuming that it gives out all the heat it receives from the sun), it can be shown by calculation that the moon would produce less than one three hundred thousandth part ($\frac{1}{300,000}$) of the heating effect on the earth that the sun does directly. For example, if we assumed that the sun in a given time was able to melt a thickness of four miles of ice at the earth's surface, the moon could not possibly melt more than an inch in the same time.

It is hence evident that whether we consider the moon as an attracting body, or as a source of heat, its energy or power is exceedingly small, compared with that of the sun. The total power of the moon on the atmosphere, which is chiefly influenced by heat, bears about the same relation to that of the sun as a molehill to a mountain. To refer these large and violent atmospheric disturbances called storms to the moon—a feeble cold mass—is, to say the least, to assign an utterly inadequate and feeble cause to a very large and massive effect. Meteorologists hence almost universally assume that the sun is directly or indirectly the agent or the motive power which produces all the larger changes or motions in the earth's atmosphere. It is its energy alone which maintains the steady Trade-winds from year to year and the periodic monsoon winds of India, and which sets in motion those fierce destructive hurricanes or cyclones of the Indian and Atlantic Oceans that are the dread of the sailor.

Air motion.—We have thus seen that the air is a heavy substance, and that in order to put large masses of it into rapid motion, and more especially to originate the enormous motion of a large cyclonic storm, the expenditure of a vast amount of power is necessary and that this power or energy is derived ultimately from the sun.

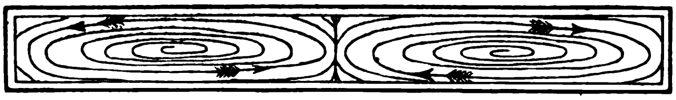
Character of air motion on large scale.—There are certain peculiarities in air motion which it is desirable to explain. The atmosphere forms a continuous mass surrounding the earth, which has a lower surface, because it rests against the earth's surface, but which almost certainly has no upper surface like that of the waters of the ocean, so that there is in the atmosphere nothing akin to the waves of the oceanic waters.

Hence, when there is prolonged motion in such a mass as the open air, if we consider the onward motion of any portion, it is evident that the air in front of that portion must be also moving onwards and vacating the space to be filled by the advancing air, and also that the air behind the advancing portion will move forwards to fill up the space vacated. Hence the motion of air at any point also necessarily implies that the air is moving in front and behind. And the same will be true for these two portions of air in front and rear, and so on. The same argument continued will show that the only prolonged air-motion possible is one which returns finally into itself or motion in a circuit or closed path.

Air motion is chiefly circulation.—It resembles to some degree the motion of a continuous band such as is used for driving machinery or that of the electrical current (as it is usually considered) in a continuous wire. When the air is moving on the large scale it is hence in all cases moving more or less in a circuit. Thus, in the case of the Trade-winds the air moves over the earth's surface for some considerable distance from the Tropics to the Equator (roughly speaking); then rises up over the equatorial regions, and turns at a considerable distance above the earth's surface and moves in the upper regions of the atmosphere in a direction opposite to that near the earth's surface and then descends to the earth's surface again near the Tropics. *The simplest term for the whole motion in such a circuit is circulation.*

The north-east and south-east Trade-winds form part of such a motion or circulation. Such a complete motion as that of which the two Trade-winds form the lower portions may be represented as in the following diagram:—

FIG. 1.



North-east Trades. Equator. South-east Trades.

Winds which form part of such circulations as the above are usually steady winds which either prevail always, as, for example, the Trade-winds, or else for a definite portion of the year, as the north-east and the south-west monsoon winds of the Bay of Bengal and Arabian Sea. They are rarely violent, and are never as a rule in their ordinary state stormy winds. The average force of the south-east Trade-winds in the Indian Ocean and of the monsoon winds in the Bay of Bengal varies from 3 to 5, as measured by the Beaufort scale, in which a calm is denoted by 0, and hurricane winds by 12.

It is also interesting to note that the rain given by such a circulation falls most largely in the area over which the air is ascending, and that very little rain falls over the area where the air is descending. This is the chief reason of the heavy rainfall in the Doldrums or Belt of Calms near the Equator and of the remarkable deficiency of rainfall near the Tropic of Cancer in Africa and Asia. It also helps to explain the comparative absence of rain and dryness of the air in Northern India during the cold weather or north-east monsoon, as the air is then descending over it and moving southwards in the Bay, and of the abundant rainfall over nearly the whole of Northern and Central India in the south-west monsoon. For the southerly surface-winds of the Bay of Bengal and Arabian Sea at that season pass into Northern India and rise up or are continued as an ascending current over Northern India.

Air motion of expansion and contraction.—Another kind of motion of air that may occur is such as happens when a hollow ball of thin India-rubber, &c., is held near a fire. The air inside is heated and the elastic and flexible cover is driven slightly outwards, so that the air inside occupies a slightly larger volume than before. In ordinary language the air expands and motion of some kind is necessary to expansion. The motion, however, of the air in this case is quite different to that which would occur if the bladder were to burst. Any portion of air out in the open is in reality surrounded by a wall of air which, like the membrane of the ball, can be thrust outwards by the expansive action of the air within it when heated, so that the given portion of air occupies a larger volume than when it was colder. This takes place as a necessary result of heating. There is no doubt that this motion of expansion by heating and, therefore, also contraction by cooling occurs on a large scale in nature. It is very probable, if not quite certain, that one of the daily effects of the sun's heat is to cause an upward expansional motion of this kind (with perhaps slight horizontal movement, especially between sea and land and between plains and mountains) which is followed by contraction at night as the air cools down again. The expansion is of course due to, and accompanies, changes of pressure. Where the action of the sun is large and regular, as in the tropical regions, the motion

goes on with great regularity from day to day, and gives rise to the very regular changes in the height of the barometer known as the diurnal tides or diurnal oscillations of the barometer. These evidently are in no way due to the double action of the sun and moon as in the case of the ordinary ocean tides. They have no such variation as that of neap and spring tides, and they occur at almost equal intervals determined by the sun's apparent period of revolution round the earth, and not by the moon's. This, it may be added, is another strong proof that the moon practically exerts no power or influence on the atmosphere of the earth.

It should perhaps be noted that the expansive motion of the air, or the upward or downward motion of the air, is usually very feeble, and is never called a wind. Winds are movements of the air parallel to the earth's surface.

Motion of small masses of air through the atmosphere, such as perhaps occurs in squalls, Nor'westers, dust-storms, &c.—Another way in which it is possible that a mass of air may move may be compared to that of a cannon ball. The given mass of air may, from some cause or other, be (perhaps suddenly or impulsively) set in violent motion and force its way through the almost quiescent air in front of it driving it aside whilst the air closes up again behind it. There are some reasons for believing that the dust-storms in Upper India and the brief wind-squalls which occasionally occur at sea during cyclonic storms may be partly, if not entirely, motion of this kind.

Hence we see that so far as we have considered the subject of air motion in its simpler aspects, the motion of large bodies of air may be either—

- (i) The slight motion accompanying expansion or contraction due to heating or cooling of the mass of air.
- (ii) The onward motion of a mass of air which has been put into rapid motion, and forces or ploughs its way unbroken through a stagnant or comparatively slow moving mass of air.
- (iii) Motion of large masses of air in a circuit or circulation. This may be—
  - (*a*) simple, as in the case of the Trade-winds,
  - (*b*) complex, as in the case of cyclones or when the motion is usually termed vorticose, which case remains yet to be considered.

There may also be any combination of the above motions. This frequently happens in the cases of No. ii and No. iii (*b*).

The most important case of combination of the above motions is that which occurs in all cyclonic storms.

Air motion in cyclonic storms.—A much more complex form of motion arises when more or less violent actions occur over an area or centre of disturbance. Thus, for example, when a very large forest is on fire, the heated air over it rises and the air flows in towards it from all sides. The air which rises up after it reaches a certain height tends to spread out and to move away in all directions. For reasons which are partly explained below, the inflow near the surface of the earth to the heated air does not take place directly, but by a species of spiral or revolving motion, forming whirls, such as are very common in water motion, even on the smallest scale. The air is in such a motion drawn in

to the centre, but not directly. It moves round the centre of the disturbance and at the same time moves towards the central area into which it is drawn and then passes upwards. Hence, when such a disturbance is started, the air at and near the earth's surface rushes towards the centre from all directions and the actual motion which results from such a rush towards a central area of disturbance and uptake is always rotatory. In the case of very small whirls such as give rise to waterspouts at sea, the whirling or rotatory motion is probably due to the fact that the air from different directions rushes in with slightly different velocities or rates. In the case of the enormous whirls which form cyclonic storms this is not the chief cause in operation. This is due to the fact that the air is connected with the earth, which is a moving body. Hence, when the air is in apparent motion, it is actually moving with respect to a body which is itself in motion.

This introduces an important action which was only brought into full notice some years ago. Before stating it, it will perhaps be better to give an illustration. Suppose a person sitting or walking about in a train moving rapidly and that the motion of the train is suddenly altered by coming in collision with another train. The man would be by this change of motion suddenly thrown forward, and the effect, so far as the man in the carriage is concerned, is just the same as if he were impelled forward by a powerful force. This is only a particular case of a general principle. If two bodies are connected and moving with respect to each other, any change in the motion of the one will produce an effect on the other which will be equivalent to the action of a force, and which may be most simply explained by assuming the existence of this equivalent force.

It is also evident that if the change is sudden, the equivalent force will be a sudden force, almost like a blow, whilst if it is gradual and continuous the force will be of the same character. Now, air, when it is moving over the earth's surface, is connected with, and moving with respect to, a body itself in motion. And, so far as one part of the earth's motion is concerned, *viz.* the motion round its axis once a day, the rate of motion differs at different parts of the earth's surface, being greatest at the Equator and diminishing to nothing at the poles. It can be shown mathematically that the effect of the air moving over the earth's surface is almost exactly equivalent to the supposition that the earth is at rest and that there is a force which is always (in whatever direction the air may be moving) tending to turn it in the Northern Hemisphere to the right hand of its line of motion. Thus it is that the air moving northwards from the Equator up the Bay of Bengal or Arabian Sea in the open sea is bent more and more to the right hand or east, and hence that the wind direction in passing northwards from the Equator up the Arabian Sea during the south-west monsoon changes from south through south-west to west-south-west. This is of course only out on the open sea, where there are no obstructions to change its course.

Hence, if any disturbance arises in the air which tends to draw the air in from all directions, the air which moves directly towards it from all quarters will be drawn aside and have its direction continuously changed as it advances towards the centre, and from whatever direction it will be deflected towards the right hand.

It is not possible to represent such a motion by a single diagram. In a vertical section through the centre the motion would be somewhat as follows:—

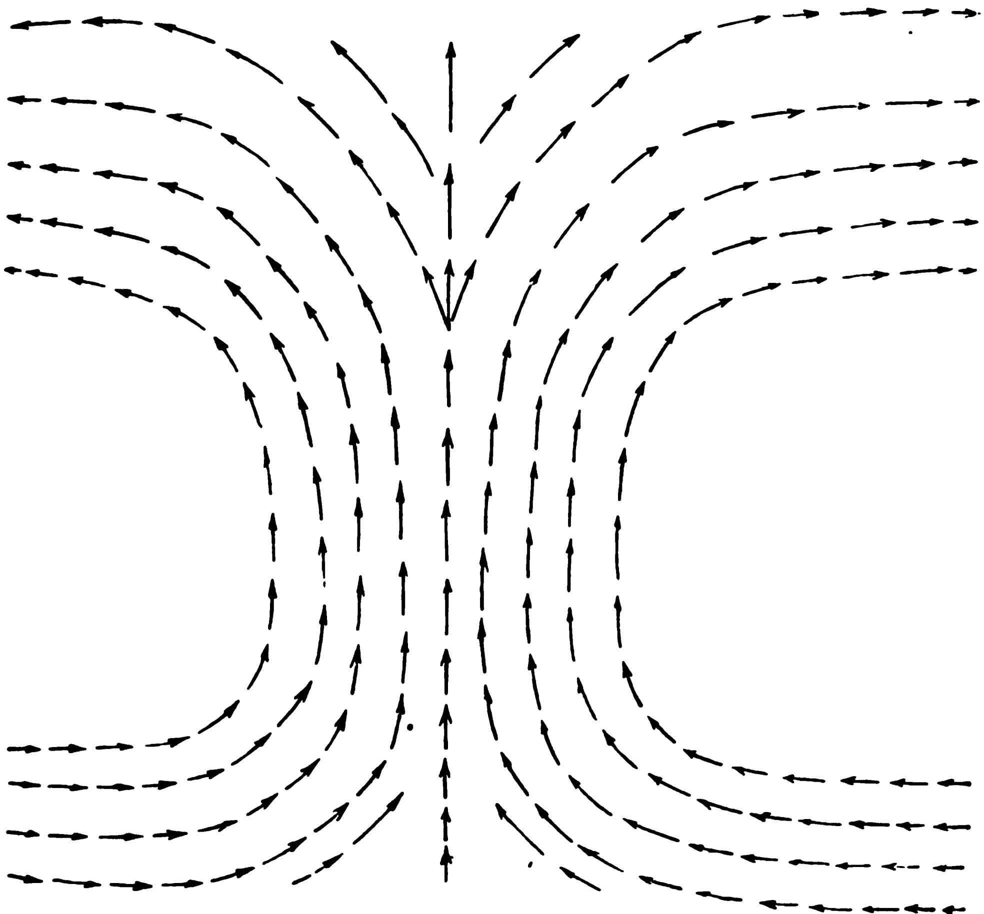


FIG. 2.

This, however, represents one feature of the motion and by no means the most important part. The air is drawn into the centre, but is not drawn directly to it. The particles move by a kind of spiral path to the centre figured as below, and hence tend to carry bodies inwards by such a path—

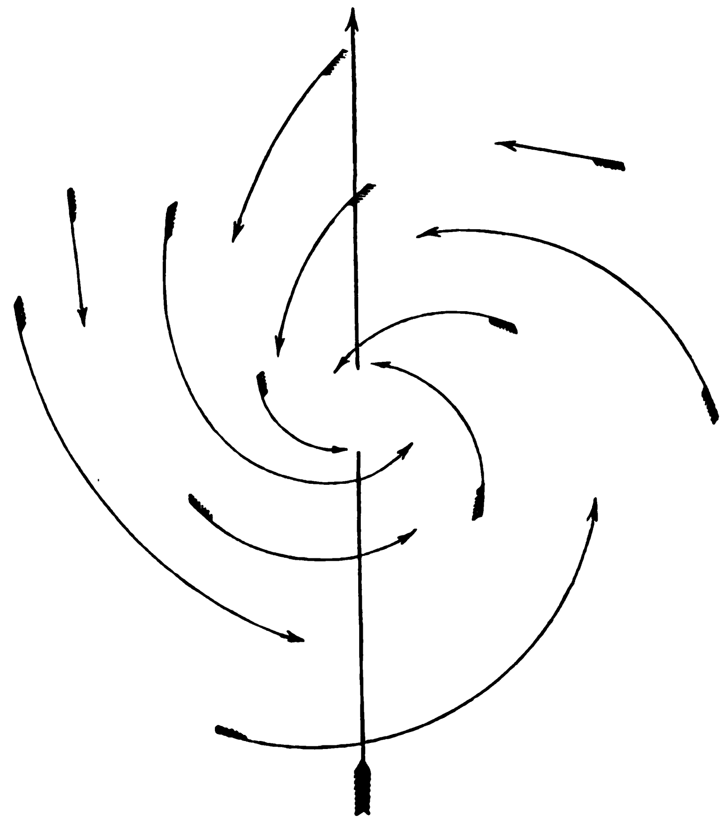


FIG. 3.

It is most important to remember that the air moves in this manner when there is a central disturbance giving rise to a rapid motion of the wind about he centre and of indraught towards the centre. It has been stated by several of the older meteorologists that the air moves round the centre in a circle as a point on the rim of a wheel moves round the axle, and that, therefore, the direction of motion of the wind is at right angles to the direction, or bearing, of the centre. Every cyclonic storm that is investigated, in whatever part of the world it occurs, furnishes fresh evidence of the error of Piddington, Reid, and others on this point, and confirms the spiral theory of the motion of the air in cyclones. Such a motion of the air is called a cyclonic circulation and ***may be very feeble, or it may be so violent as to constitute a dangerous storm.***

Cyclonic circulations have certain general features, the chief of which should be carefully remembered:—

1st—The barometer is always low at or near the centre, and is high on the outskirts, or outer edge, of the circulation, and diminishes as we proceed from the outskirts to the centre. The fall is also usually most rapid near the centre.

2nd—The air near the earth's surface not only moves round, but is drawn in towards the centre and moves always in the same direction with respect to the centre in the north hemisphere. The air moves round in a direction which is the opposite to that in which the pointers of a watch move, so that, roughly speaking, to the east of the centre southerly winds prevail, to the north, easterly winds; to the west, northerly winds, and to the south, westerly winds. Hence the direction of the wind in a cyclonic storm indicates to an observer in what part or quadrant of the storm area he is.

This motion is usually known as the cyclonic motion of the wind in the northern hemisphere, and is frequently denoted thus—

3rd—At and near the centre over which the air is ascending there is much development of cloud, and frequently heavy rainfall, whilst in the outskirts, where there are descending currents, fine clear dry weather is the rule, and there is a gradual transition from the one kind of weather to the other as we pass from the outskirts to the centre and *vice versâ*.

The reader should hence remember that to a meteorologist what is called a barometric depression, or low barometer, over an area relative to neighbouring districts and a cyclonic circulation are similar terms and suggest the same kind of air motion or disturbance. If the motion be violent, it of course forms what may be termed a cyclonic storm or cyclone, and if excessively violent, a hurricane.

The following are three examples of cyclonic circulation from the ordinary observations in India itself:—

The first gives the air motion in Bengal on the 27th May 1886 at 10 A.M., when the Balasore cyclone was passing northwards into Behar. The winds are deduced from land observations where there is no difficulty in obtaining accurate measurement of its direction. The chart shows the incurving of the winds most strikingly, and is such as always occurs in a cyclonic storm in its passage over land—

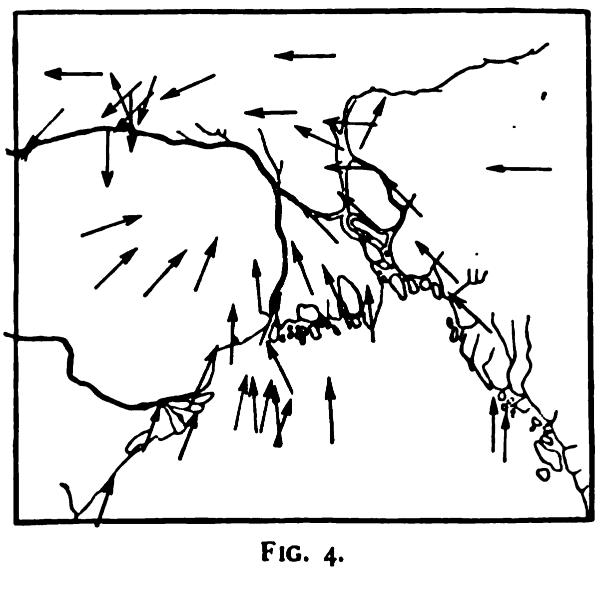


FIG. 4.

The next case gives the winds as actually recorded in the Bay of Bengal and at the coast stations on the 7th of November 1886, when a cyclonic storm was approaching the Madras coast. A very noticeable feature in this cyclonic circulation is the north-easterly winds on the coast of the Circars and Ganjam, where easterly winds would be expected. This is an example of a peculiarity which will be referred to later on more fully—

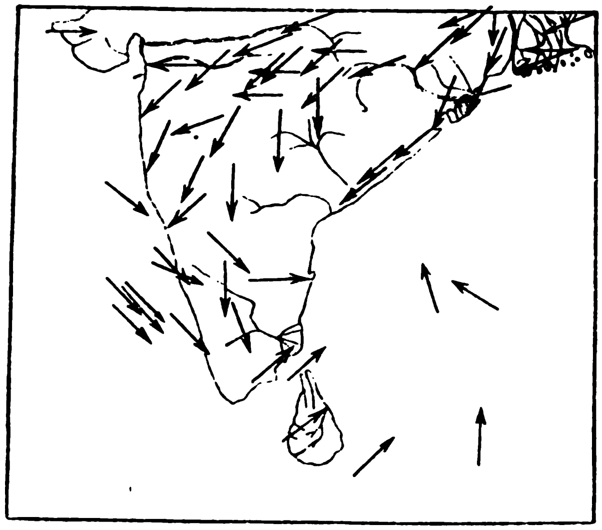


FIG. 5.

The third is a case of cyclonic circulation in India, but which is not attended with strong winds or squally weather. It is a chart showing the ordinary weather conditions in Bengal on dry hot days in April and May. In this case merely the isobars and wind directions are given. They show the incurvature of the winds to an area of slightly deficient pressure as markedly as in the preceding cases—

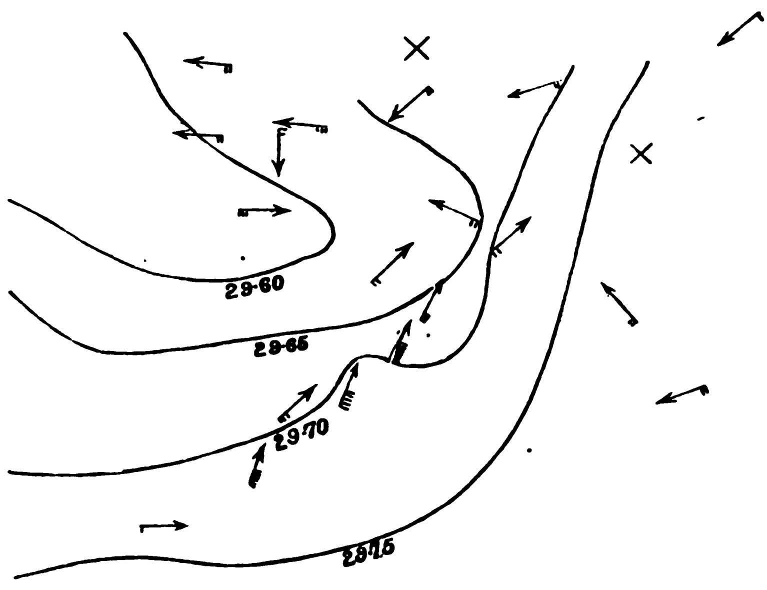


FIG. 6.

The following case is given of a cyclonic circulation and storm passing across the United States in America, as it shews even more strikingly than the cases already given the incurvature of the winds, and further illustrates that the principle is a general one, applicable in all seas and countries.

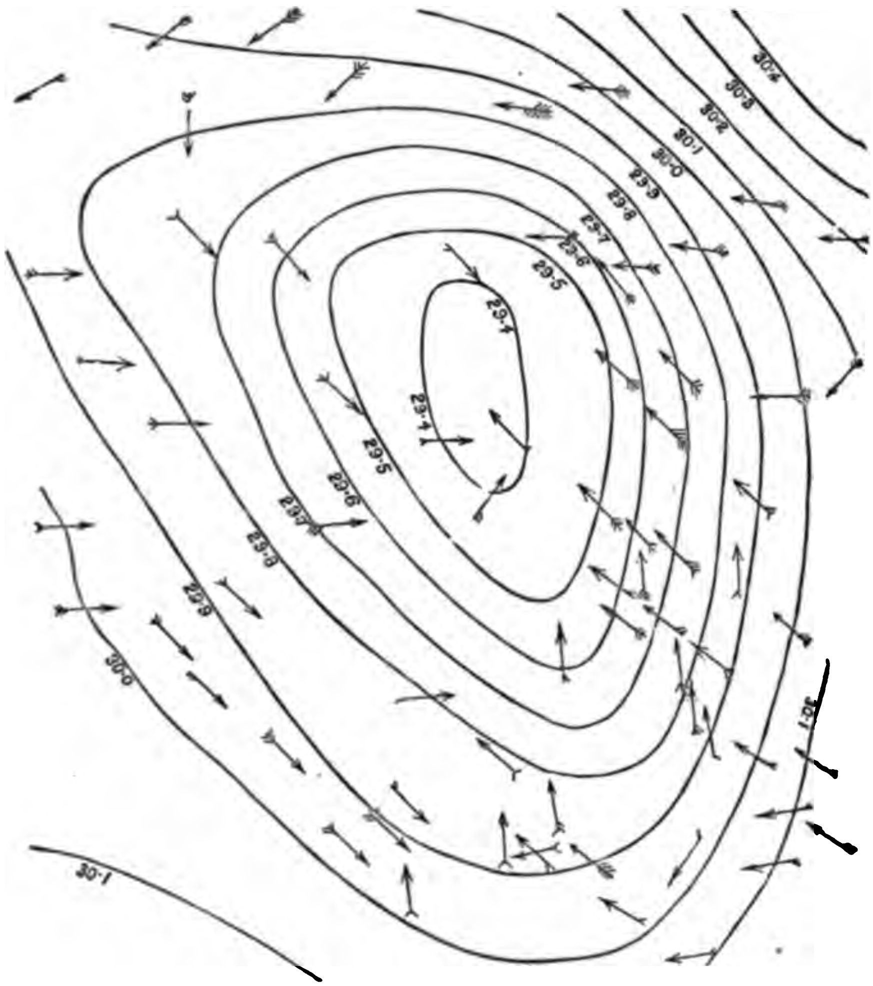


Fig 7.

Motion of the air in an anticyclone.—The same general kind of motion about a centre, but in the reversed direction, can be produced in various ways, as, for example, by great cold or by the fall of snow over a large area. The effect of the cold would be to produce a descending current, and hence near the surface of the earth the air would move away, the motion not taking place directly from or round the centre, but in a spiral or vorticose manner, and above the air would stream in by a similar kind of path to feed the descending current.

The chief features of such a motion are the opposite of those of a cyclonic circulation.

1st—The barometer is highest near the centre and gradually falls as we pass from the centre outwards.

2nd—The spiral motion of the air about the centre is performed in the opposite direction to that already described, or, in other words, the air moves round in the same sense or direction as the hands of a watch. The direction is usually shewn in the following manner :—

Such a motion of the air is termed anticyclonic and the whole phenomenon an anticyclone. The motion of the air in an anticyclone is very rarely violent and never in temperate or tropical seas, and hence it is not necessary for a sailor to study the relations between the wind directions and the centre of an anticyclone, if he is merely anxious to know sufficient to enable him to take the precautions necessary to enable him to avoid danger when he is involved in a storm.

Wind.—As the direction of the centre of a cyclonic storm is chiefly determined by means of the direction of the wind and its changes, it is very important that sailors should estimate it as carefully and exactly as possible.

The direction of the wind is recorded according to the points of the compass ; at the land observatories in India it is estimated according to the following sixteen compass-points, which are found to be sufficient :—

NAME.	Symbol.	Arc.
North	N.	°
North-north-east	N.-N.-E.	22° 30′
North-east	N.-E.	45°
East-north-east	E.-N.-E.	67° 30′
East	E.	90°
East-south-east	E.-S.-E.	112° 30′
South-east	S.-E.	135°
South-south-east	S.-S.-E.	157° 30′
South	S.	180°
South-south-west	S.-S.-W.	202° 30′
South-west	S.-W.	225°
West-south-west	W.-S.-W.	247° 30′
West	W.	270°
West-north-west	W.-N.-W.	292° 30′
North-west	N.-W.	315°
North-north-west	N.-N.-W.	337° 30′
Calm	C.	

In the case of land observatories it is determined by means of a wind vane, which has been carefully fixed in position, so that the direction is correctly given by the indications of the instrument. In the case of a ship at sea, this is not possible, as a wind vane would not give the actual wind direction, but the apparent wind direction as observed by a moving body, which is of course different from the former by an amount dependent on the speed and direction of motion of the vessel.

The only method in general use of measuring wind force at sea is by estimation. It is somewhat rough, but the general agreement of the wind observations contained in the logs which have been sent in to the Bengal Meteorological Office indicates that it is much less dependent on the individual observer than might at

first sight be supposed, and that, as employed by sailors, it gives consistent and valuable results. The scale generally adopted by sailors is that devised by Sir F. Beaufort when in command of Her Majesty's ship *Woolwich*, and is based upon the pressure exercised by the wind on the sails of a ship. It is, on the whole, the best that has as yet been suggested, and has also the additional merit of being in general use on board English ships. It is as follows:—

Scale.

Number used to denote wind.	Character of wind.			Velocity of wind in miles per hour.
0	Calm			0 to 3
1	Light air, just sufficient to give steerage way			8
2	Light breeze	or that in which a well-conditioned man-of-war with all sail set, and clean full would go in smooth water from	1-2 knots	13
3	Gentle breeze		3-4 „	18
4	Moderate breeze		5-6 „	23
5	Fresh breeze	or that in which she could just carry in chase	Royals, &c.	28
6	Strong breeze		Single-reefed topsails or topgallant sails.	34
7	Moderate gale		Double-reefed topsails, &c.	40
8	Fresh gale		Triple-reefed topsails.	48
9	Strong gale		Close-reefed topsails and courses.	56
10	Whole gale, or that in which she could scarcely bear close-reefed main topsail and reefed foresail			65
11	Storm, or that which would reduce her to storm-staysails			75
12	Hurricane, or that which no canvas can withstand			90

The velocities given in the last column have been determined in the English Meteorological Office.

It is very important that sailors should determine the direction of the wind to the true north. There is little doubt that the directions as given in the logs of vessels are frequently erroneous, more especially those taken during cyclonic storms, from no allowance being made for the deviation of the compass due to the heeling of the vessels.

It may also be here noted that on land the direction of the wind is very considerably modified by the inequalities of the surface which obstructs the free motion of the air. Out on the open sea the wind directions observed in cyclonic storms are due to the cyclonic circulation undisturbed by other actions. Near the head of the Bay, more especially in the north-west of the Bay, the wind is affected to a very considerable extent by the proximity of the land, more especially in the outskirts of cyclonic storms where the winds are comparatively

feeble. It is probably in part due to this that the wind in the north-west angle of the Bay hangs so long at N.E. on the approach of cyclonic storms.

Relation between wind and pressure.—It has been already pointed out that even in the finest weather the barometer at the sea-level not only varies in height from day to day and from hour to hour at the same place but also varies from place to place at the same instant. It is also found, more especially in tropical regions, that the barometer varies fairly regularly in going from place to place at the same instant. Hence it is that at the same hour the barometer is low in certain districts and high in others. An area in which the barometer (reduced to sea-level) stands at a lower level than in neighbouring districts is called an area of barometric depression or an area of depression. The weather charts published by India and other Meteorological Departments give special prominence to areas of depression, for stormy weather is invariably found in such areas. These depressions may be of small extent and amount or they may be large. It is, however, most important to remember that all such depressions, however they may differ in size and intensity, have certain features in common. These have been already stated in connection with air motion, but it is desirable to re-state them. In such an area it is found that pressure diminishes with approximate regularity from the outside of such an area to some point within it. This point is conveniently called *the centre of the depression*. It is also found that in such an area the air moves in a rotatory manner in such a way that it is not only moving round the centre but also is drawn into it, or in fact that the air motion in such an area always forms a cyclonic circulation. Such areas of low barometer or barometric depression are not permanent. They commence to form and increase for some time in size and intensity, at the same time that they usually appear to advance in some direction, just as a temporary whirl in a stream of water moves for some time along with the stream and then disappears. After some time the barometer rises in the area, and the depression gradually fills up and disappears. *It should, hence, be carefully borne in mind that an area of barometric depression is necessarily an area of cyclonic circulation, and also that if the depression increases in amount and becomes large, the cyclonic circulation, which is at first feeble, becomes more and more rapid, and may gradually develop into a cyclonic storm or hurricane. Cyclonic storm areas are always areas of barometric depression and of cyclonic air circulation. A cyclonic circulation denotes a particular kind of air motion irrespective of whether the air motion is feeble, moderate or violent. A cyclonic storm, cyclone, hurricane, or typhoon is a rapid or violent cyclonic circulation.*

The preceding remarks have shown that in an area in which the barometer falls from the outside to a central point, the barometric depression is invariably associated with a particular kind of air motion. This is an example of a very important meteorological principle, *viz.*, *that winds are strictly and closely related to changes of pressure*. It is hardly necessary to state that pressure plays exactly the same part with reference to air that slope or level does with respect to water. If the water stands at the same level everywhere, there will be no motion. If, on the other hand, there is a difference of level, and the water is free to move, it will at once commence to

move from the higher to the lower level. Similarly, if at the level of the sea the barometer stood everywhere at the same height, or pressure was uniform, or unchanged, from place to place, the air would be at rest or in equilibrium. If, on the other hand, it diminishes from one district to another, it is always found that the air is in motion from the district of higher pressure towards the district of lowest pressure. If the pressure diminishes very slowly, the winds are found to be gentle, but if large, the air moves rapidly. In fact, just as water moves more rapidly down a slope the steeper the descent, the more rapidly does air move as the pressure diminishes more rapidly with distance. Hence it is clear we want a term to express the rate at which pressure increases or diminishes from one point to another on the earth's surface. The term now used by all meteorologists is "*baric gradient.*"

Baric gradient.—The term "gradient" is very largely used in connection with railways. It is clear that a rise of 20 feet in one mile is twice as great a rise as a rise of 10 feet in a mile, and that a rise of 45 feet in one mile is five times as great a gradient as that of 9 feet in one mile. It is hence evident that a comparison of slopes or gradients is the same as that of two numbers (45 to 9 in the last case, and 20 to 10 in the former case) so long as the rise or fall is given for the same distance, and this is what is usually done in estimating gradients.

In other words, when the rise or fall of level of a railway, &c., is calculated at so much per mile (or any other definite unit of length), it is termed the gradient, and the comparison of two gradients is simply that of two numbers and can be made without trouble and with hardly any calculation. It would, however, require a longish calculation to compare a rise of 15 feet in 1,194 feet with one of 365 feet in five miles and to ascertain which was the greater slope. The advantages of this practical method of comparing slopes or gradients are hence self-evident.

The term was so suggestive and enabled certain comparisons to be made so easily that it was introduced into the language of meteorology many years ago. It has already been stated that whenever strongish winds are blowing. differences of pressure obtain at the sea-level, and that the stronger the winds the more rapidly does the barometer fall. Hence the great principle that the strength of wind depends upon the differences of pressure. When the differences of pressure are stated for a given fixed distance, they are termed baric gradients. The fixed distance that was usually chosen until three or four years ago was a geographical degree, or 60 knots. For instance, if the difference of the height of the barometer at two places 7° apart was ·14" or fourteen hundreths of an inch, the baric gradient would be $\frac{1}{7}$ of ·14", or two hundredths, and so on. The units now selected and used by international agreement are respectively one hundredth of an inch of pressure, and fifteen geographical miles for distance (corresponding to one millimetre and one degree or sixty geographical miles).

The principle stated above may hence be expressed as follows:—*The direction and strength of the winds depend upon the direction and amount of the baric gradients or pressure slope.*

The relation is somewhat complicated, and has been expressed more or

less imperfectly in various mathematical formulæ. It will be sufficient for the sailor to state it roughly in words.

Relation between Wind Direction and Baric Gradients (Buys Ballot's Law).—The principle laid down in the preceding paragraph holds good universally, and the relation of the wind direction at any place during a cyclonic storm and the bearing of the centre is only a particular case of the general principle. Professor Buys Ballot, of Utrecht, was the first in Europe to draw attention to its great importance, and stated the relation in a simple form as follows:—

"*In the Northern Hemisphere stand with your face to the wind and the barometer will be lower on your right hand than on your left.*

"*In the Southern Hemisphere stand facing the wind and the barometer will be lower on your left hand than on your right.*"

These two principles are hence recognised as Buys Ballot's Law. By their employment we can tell, knowing the direction of the wind at any place, in which direction the barometer rises or falls, and if we know in which direction the barometer falls or rises most rapidly, we can at once state what wind is blowing at the place.

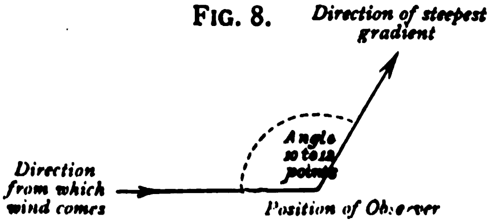
For example, suppose that northerly winds are blowing at the Sandheads. Look northwards (to face the wind), Orissa is to the left and Arakan to the right. Hence pressure will decrease in going from the Sandheads eastward towards the Arakan coast, and increase in going westward towards the Orissa coast. And so on for other cases.

The relation as stated in the preceding law, or principle, is not definite enough in the case of the barometric depressions in which the air motion is strong or violent. The subject will be discussed more fully in the next chapter. The following statement will be sufficient for ordinary use.

Fuller statement of the relation between Baric Gradients and Wind Direction.—The relation between the baric gradients and winds may be stated as follows:—

Starting from any place the barometer will fall in a certain range of directions and rise in the remaining range of directions. There will be one direction of most rapid fall of the barometer which will be the steepest gradient. Suppose you stand so that this direction of the steepest gradient is to your right hand, then you will face the wind, which will come from a direction varying from 10 to 12 points from the direction of the gradient and its strength will depend upon

FIG. 8.



the magnitude of the gradient. If the gradient be small the wind will be of force 0 to 3, and will increase rapidly in strength with increase of gradient.

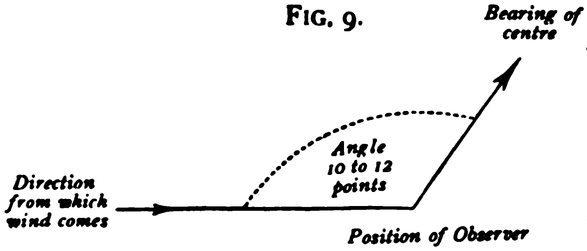
Thus, the gradients in the Bay are from north to south during the north-east monsoon and usually vary from one to one and a half hundredths of an inch

per degree. The winds are then from north-east and of force varying in ordinary weather from 1 to 3. During the south-west monsoon (in July, August, and September) the steepest gradients are *in ordinary weather* from south to north, and are from two to three hundredths of an inch per degree,—that is, the ordinary gradient in the south-west monsoon is about twice that of the ordinary north-east monsoon, and the average force of the wind appears from logs to vary from 2 to 6, and averages about 4.

Gradients rarely exceed three or four hundredths of an inch per degree (or 12 to 16 units of gradient according to the new notation) in the Bay of Bengal except within the area of a cyclonic storm. As the centre is approached, the gradients become steeper and steeper, and in the case of the most intense cyclones very steep gradients occur. The most remarkable and steepest gradients that have ever been observed occurred during the False Point cyclone. The difference between the height of the barometer at a distance of about 35 miles from the centre and that at the centre was upwards of two inches (2·4 inches), which is equivalent to 480 hundredths of an inch per geographical degree (or 1,920 units), or nearly two hundred times as steep as the ordinary gradient of the month in which the storm occurred in the Bay.

The most important application of these principles is in the case of cyclonic storms. The direction of the steepest gradients at any position in the storm area coincides with the direction, or bearing, of the centre. Hence, as a particular case of a perfectly general principle, is based the rule that is frequently given—

FIG. 9.



To find the bearing of the storm centre at any position within a cyclonic storm, face the wind exactly, and the centre will be on your right hand and from ten to twelve points from the direction whence the wind comes.

This angle between the two directions, *viz.* that from which the wind comes, and that of the centre will be called for convenience *the bearing angle.* The method of finding the centre is illustrated in the above diagram (Fig. 9).

This point will, however, be examined and discussed more fully in the second chapter and fuller rules given for the application of the principle to the determination of the bearing of the centre of cyclonic storms.

The Barometer.—The barometer is the only meteorological instrument which is universally employed on board ship by mariners in judging of approaching stormy weather. It is also the chief instrument used in all meteorological observatories, and it is mainly by means of barometric observations transmitted by telegrams that the meteorologist in his office is enabled, not merely to follow the course and phases of a storm, but to issue useful and reliable forecasts and to hoist warning signals. Sailors, although they are more interested than any other class in accurate fore-knowledge of the weather are too often found to despise the more exact methods of modern meteorologists and to rely

solely upon sky and weather indications. I believe it is not too much to say that not one captain in three navigating in the Bay of Bengal uses his barometer in such a way as to be of any real service in judging whether he is approaching a storm or cyclone, or not.

The barometer is a simple scientific instrument or tool, and requires to be properly used to be of value. In the hands of an accurate and intelligent observer its indications are of the greatest value. It is employed for the purpose of finding the pressure of the air at the time and place of observation, and if properly utilized gives the observer certain and definite information from which to infer the present and probable future general character of the weather, so far as it can be determined by its use.

Necessity for the use of accurate and trustworthy Barometers.—The first requisite for accurate and useful measurement is a good instrument. The sailor recognizes this most fully in the case of chronometers. He uses the best and most accurate he can procure. He is provided with, and employs, usually two or three, for he recognizes that human workmanship is never perfect, and that no chronometer will keep exact time, and that it is therefore desirable to have several to check each other and thus enable him to obtain as accurately as is possible on a long voyage a determination of Greenwich time. He compares them at every available opportunity with standard clocks, time-ball signals, &c., and thus determines their errors and rates as frequently as he can. In every calculation he makes to find his longitude he allows for the error of his chronometers,—that is, for its deviation from *standard Greenwich time*, which is determined ultimately by the apparent motion or meridian transit of the sun at Greenwich, or by the real motion *of the earth about its axis*. The meteorologist believes that the same care and similar precautions are necessary in the case of barometers. And what he does the sailor ought to do if he wishes to derive the fullest advantage from the use of his barometer.

He must be prepared to recognize that care should be taken in the selection of a barometer in order to obtain a good and trustworthy instrument. He should have at least one mercurial barometer on board. Many sailors prefer aneroids. They are undoubtedly very handy, and generally follow and indicate changes of pressure more quickly than the marine barometers in ordinary use do. But they have one very serious disadvantage which should never be overlooked. The visible and considerable motion of the needle of an aneroid barometer is obtained by magnifying an exceedingly small motion of the lid of a closed box by means of multiplying gear or chain levers. The aneroid barometer itself is a small hollow box formed of thin steel, the elastic top of which is pressed inwards or outwards as the pressure of the air outside increases or decreases. The space through which the top of the box moves is exceedingly small. It is this motion, magnified or multiplied by suitable arrangements, which gives motion to the pointer. It is evident that a very slight change in the metal of the box or of the connecting chain-work due to climatic influences or to rough usage (as, for example, the transition from the cold of an English winter to the heat of Bombay or Calcutta in March or April) may, when exaggerated by the multiplying gear, produce a considerable change or error in the indication of the pointer. A chronometer in which the time was determined solely by means of

the magnification of the motion of the hour hand,—as, for example, by microscopes,—would hardly commend itself to any one, and least of all to a sailor.

It will suffice to give a single illustration from recent experience of the very large errors of aneroids actually in use on board some steamers in the Indian seas. It may be remembered that one of the more remarkable cyclonic storms of the transition period of 1888—(*viz.* that which formed in the Bay of Bengal in the last week of October 1888)—crossed the Peninsula, passed out into the Arabian Sea on the 2nd November as a general disturbance, acquired increased energy, and re-formed as a cyclonic storm which moved to north-east, and crossed the coast of Kattiawar on the morning of the 9th, and broke up on the 10th in West Rajputana. The chief disaster attending the storm was the disappearance of the coasting steamer *Vaitarna* with several hundreds of native passengers on board. She was apparently overwhelmed by a heavy sea, and went down with all on board. In connection with the enquiry on the loss of that vessel, the Port Officer of Bombay asked the Meteorological Reporter for Western India to compare the aneroids in use on board of the other steamers of the line to which the *Vaitarna* belonged. He found that each vessel was, with one exception, supplied with one aneroid barometer, and that the errors of these instruments, as compared with the standard barometer at Bombay, were as follows:—

Vessels.		Error of aneroid on board the steamer as determined by comparison with Bombay standard.
Steamer	No. 1	·25" too high.
"	No. 2	·37" too high.
"	No. 3	·40" too high.
"	No. 4	·06" too low.
"	No. 5	Aneroid No. 1 ·56" too high.
		" No. 2 ·14" too high.
"	No. 6	·03" too low.
"	No. 7	·46" too low.

This table shows that the errors of several of these instruments were nearly half an inch in amount,—in one case nearly half an inch too low, and in three other cases nearly half an inch too high. It is hence quite certain from what is known of the height of the barometer in ordinary storms in the Bay of Bengal and Arabian Sea that these aneroids would give utterly unreliable and fallacious information. Thus, those aneroids which read half an inch too high would apparently indicate fine-weather conditions in the midst of a cyclonic storm, and those which read half an inch too low would give readings in fine weather such as usually only occur in cyclonic storms with trustworthy barometers, and would apparently indicate a cyclonic storm when the weather was fine and settled. It is of course possible that the only use made of them was to ascertain when the barometer was falling or the air pressure decreasing rapidly. If this be the case,

even then such instruments are of little service in showing the approach of a cyclone, as barometers rarely fall rapidly until the inner, or dangerous, portion of a cyclonic storm is close at hand.

The defects of the aneroid are so well known to meteorologists that, in spite of its compact form and its sensibility, it is never used in regular observatories, or in any case where accuracy is essential, unless it can be carefully and frequently compared with a good mercurial barometer. It may hence be laid down that *aneroids should only be used so long as they can be frequently compared with a mercurial barometer to ascertain that they are in good working order and giving correct indications or readings. It is only under such conditions that their readings can be accepted as trustworthy. It is hence necessary that all ships should have one or more mercurial barometers (by a good maker) which have been carefully compared with a standard and their errors determined, and that any aneroid on board should be employed only so long as its readings correspond with those of the mercurial barometer.*

As the mercurial barometer is by far the most important meteorological instrument for use on board ship, it appears to be desirable to give a description of that particular form of it—"the marine barometer"—which is best adapted for use at sea, and of the proper methods of reading it.

The Marine Barometer.—The barometer consists essentially of a vessel of mercury, called the cistern, into which dips a glass tube, usually about 33 inches long, closed at the upper end and open below, and of a scale for measuring the height at which the upper surface of the column of mercury inside the tube stands above the level of the mercury in the cistern.

The principle upon which the use of the barometer is based is illustrated by the following experiment, first performed by Torricelli, an Italian mathematician who lived upwards of two hundred years ago.

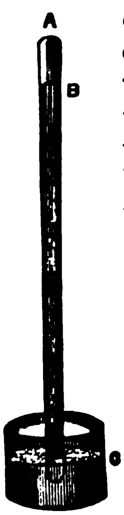


Fig. 10.

Take a glass tube (fig. 10), about 33 inches in length, open at one end and closed at the other. Fill it with mercury, and after closing the open end with the finger, invert it, and dip the open end into a vessel containing mercury and then withdraw the finger. The upper surface of the column of mercury will fall down a little distance to the position B, where it will remain steady. If the experiment be performed near the level of the sea in fine weather the upper surface of the mercury in the tube will be found to be at a height of about 30 inches above the level of the mercury in the cistern or vessel. The upper space AB is practically a vacuum. The column of mercury in the tube is kept up, or supported, by the pressure of the air on the surface of the mercury in the cistern. This is at once proved by the fact that if the whole arrangement were put inside a large glass receiver connected with an air-pump, and the air gradually withdrawn, it would be found that the column would diminish in height at exactly the same rate as the air was withdrawn. And if the whole of the air was withdrawn, so that there was none left to press on the surface of the mercury in the vessel, the upper surface of the mercury in the tube would stand at the same level as the mercury in the vessel.

Such an arrangement as is shown in the figure, with the addition of a scale, in fact constitutes a barometer in its very simplest form. Other parts are usually added, partly for the protection of the instrument (as the use of a brass tube enclosing the glass tube) and partly to enable the height of the mercury column to be measured very accurately (*e.g.*, a vernier and adjusting screws, &c.). As barometers intended for use at sea are very liable to breakage by the rolling and pitching of the vessels, it is necessary to modify these instruments in such a way as to prevent this so far as possible. This is generally done by narrowing the tube through the greater part of its length. This usually prevents the rapid motion (or pumping) of the mercury in the tube, which is the chief cause of the breakage of the tubes of barometers at sea. A barometer in which such a tube is used forms what is termed a "marine barometer." The best form of marine barometer is that which is adopted by the Admiralty and the English Meteorological Office, and was approved by the Brussels Conference of Meteorologists some years ago, as the barometer best suited for withstanding the shocks due to the motion of ships and for giving accurate barometric observations. Its form and mode of suspension are shown in fig. 11.

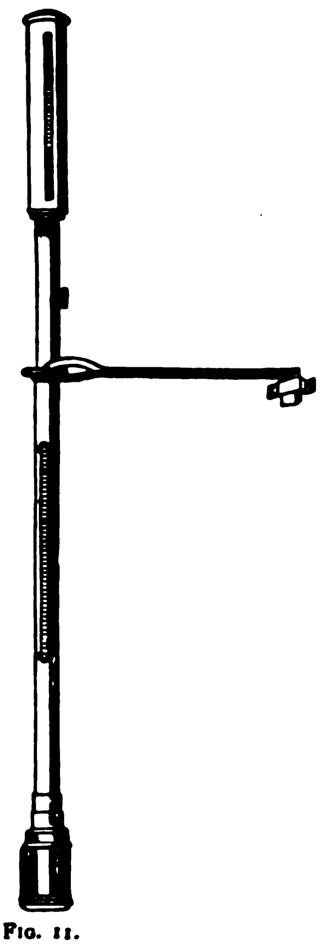


FIG. 11.

The cistern is made of bronzed polished iron. The frame is brass bronzed and revolves in gimbals, having a stout spring arm for suspension. The scale reads to two thousandths of an inch. The tube is contracted sufficiently to prevent oscillation of the mercury in the heaviest rolling of a ship. This kind of barometer is supplied by any of the best scientific makers,—*e.g.* Casella, Negretti and Zambra, &c.,—and is priced at £4 5*s.* in Casella's catalogue. Every sea-going vessel ought undoubtedly to be provided with at least one such barometer.

Verticality of the Barometer.—It is evident that the height of the column, which is the object of the measurement, is the distance in a vertical line between the surface of the mercury in the cistern and the top of the column. It is hence absolutely essential, for accurate measurement, that the barometer should be perfectly vertical. This is, of course, secured in the case of the marine barometer recommended for use by the mode of suspension.

Adjustment for varying level of the mercury in the Cistern.—It has been stated that the height or distance to be measured by the scale attached to the barometer is that between the surface of the mercury in the cistern and the top of the mercury column in the tube. As the amount of mercury in the barometer tube and cistern does not alter, it is evident that when the top of the column sinks

in the tube (*i.e.* the barometer in ordinary language falls), the amount of mercury in the tube will be less, and some mercury will have passed out into the cistern and raised the level of the surface of the mercury in the cistern. The scale is, however, fixed to the tube in marine barometers, and hence the lower end of the scale from which the measurements are made is not able to adapt itself to the surface of the mercury in the cistern, which moves slowly up and down, with the movements of the mercury column in the tube. Various contrivances have hence been devised to enable the exact height of the barometric column to be measured by the use of a fixed scale. In the case of the marine barometer, allowance is made for the rise and fall of the mercury in the cistern on the scale itself. The makers do not divide the scale into exact inches, but in such a way that the numbers as read indicate in all cases, however much the mercurial column varies, the exact height in inches from the surface of the mercury in the cistern to the top of the column. Hence, the marine barometer as thus arranged gives the exact reading without any trouble, and no subsequent correction is necessary for the changes of level of the surface in the cistern. It is in this, as in several other respects, the easiest and most convenient barometer for ordinary use.

It should be carefully noted what is meant by the top of the column. This is not a plane or flat, but a curved surface. The line which bounds the contact of the mercury with the glass is lower than the real surface would be if the tube were several inches in diameter instead of being only a fraction of an inch. If the tube were very large the surface would be almost flat and coincide in height almost exactly with the height of the top of the curved surface in a narrow tube. Hence the top, or highest point, of the curved surface should be taken as the top of the column, and not the line which bounds the contact of the mercury with the glass. The latter is unfortunately too often taken as the top by persons unacquainted with the proper method of using the barometer, and their readings are hence necessarily wrong by a certain amount depending on the inner diameter of the tube, and which consequently differs for different instruments. It should hence be most carefully remembered that ***the measurement should always be taken to the highest point of the curve.*** This is usually done by means of the vernier with which every good marine barometer, such as that recommended above, is provided. The vernier and the method of using it are described below.

Use of the Vernier.—The use of the vernier is to facilitate the accurate measurement of the height of the column. Each inch on the fixed scale of a barometer is generally divided into tenths and half-tenths of an inch, written 0·1 and 0·05. If, now, a length equal to 24 or 26 of these latter subdivisions be set off on an independent movable scale and divided into 25 parts; each of these latter subdivisions differs from a scale subdivision by $\frac{1}{25}$th of the latter; being in the one case less, in the other greater. Such a scale is called a vernier. Now, let the vernier and fixed scales be applied to each other, edge to edge, as in figs. 12 and 13. If the first mark of the vernier coincide with a mark of the fixed scale, the last will coincide also, but no other; and in all other cases only one mark of the vernier will coincide with a scale mark. Since each vernier division is $\frac{1}{25}$th greater

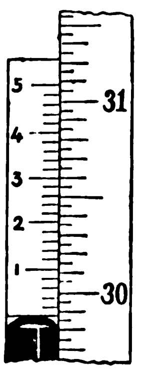


Fig. 12.

FIG. 13.

or less than a scale division, the number of vernier divisions between the coinciding mark and the zero of the vernier will show how much this zero deviates from the scale mark next below it. If the vernier scale is equal to 24 subdivisions of the fixed scale, as is the case in the marine barometer recommended for use at sea, *it reads upwards in the same direction as the fixed scale* (fig. 12); if to 26 divisions, it reads *downwards* from its own zero (fig. 13).

The vernier scale is usually engraved on a piece of metallic tube which may be moved up and down, either directly by hand, or by means of a pinion and rack. In taking a reading, the lower edge of this tube must be made to coincide accurately with the top of the mercurial columns as shown in the annexed woodcut, and this requires that *the top of the column shall be exactly on the same level as the eye of the observer* (see fig. 14). In this position, on looking through the tube, the lower edges of the vernier slide in front and behind will coincide. To set the vernier then, raise it a little above the top of the column, get both edges in a line with the eye, and then lower it slowly till these edges form a tangent to the topmost outline or highest point of the column, no part of it being covered. If the zero line of the vernier is the lower edge of the slide and coincides exactly with one of the fixed-scale divisions, that division gives the reading. If not, take as the scale reading the division next below the edge of the vernier, and add thereto the reading of the vernier.

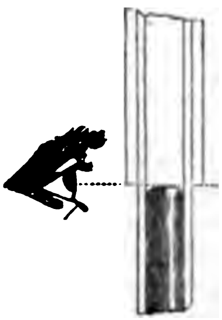


FIG. 14.

The vernier bears five principal divisions, the value of each being one fifth of the smallest *scale* division, which in the case of the marine barometer figured on page 27 is 0·01 ; and each of these has five subdivisions, or parts, each equal to 0·002". The annexed figures illustrate the use of the vernier. In fig. 12 the lower edge of the vernier intersects the scale above the division 29·85 and below 29·9. Write down 29·85 as the scale reading. Then, running the eye up the vernier, the third of the major divisions is seen exactly to coincide with a scale division. Its value, 0·03, added to 29·85, gives 29·880, which is the exact reading.

In fig. 13, the lower edge of the vernier gives the scale reading 29·8, being above 29·8 and below 29·85. The vernier mark, which coincides with a scale mark, is the fourth beyond the vernier division marked 2, and has therefore the value 0·028. Adding this to 29·8, the exact reading 29·828 is obtained. Finally, if neither of the vernier marks exactly coincides with a scale mark, but one is a little above, the other a little below, a scale division, ·001 is to be added to the reading of the lower of the two.

As a final caution, it may be mentioned that if the barometer be so suspended that the top of the column is above the eye of the observer, or if the eye is

above this level, so that the front and back edges of the vernier cannot be made to coincide, the reading will invariably be *too high.* This is owing to parallax, and is illustrated by the accompanying figure (fig. 15). The vernier *appears* to be set when its lower edge forms an apparent tangent to the meniscus of the mercury surface. If the eye be too low, the hinder edge of the vernier slide will appear to do this before the vernier is lowered to the same level; if the eye is above the top of the column, the front edge will do so. But the front and back edges of the vernier will coincide with each other, and with the mercury surface, only when all three are on the same level. Before taking the reading, the setting of the vernier must, therefore, always be verified by moving the eye up and down to ascertain, 1st, that in no position of the eye is light seen between the highest part of the surface and the edge of the vernier; 2nd, that there is one position in which the vernier conceals no part of the mercury meniscus, but only touches it.

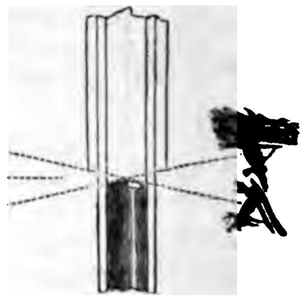


FIG. 15.

Method of reading.—First observe and write down the temperature of the thermometer attached to the barometer. If the barometer be one with a narrow tube (such as a marine barometer usually has) which acts slowly, the tube (or scale) should be gently tapped with the finger-tips before setting the vernier, and again after the first reading, when the vernier should be re-set. This should be repeated till further tapping produces no further change in the reading. The barometer should be read at least twice, and when the same number has been obtained on two consecutive readings, that number should be taken as the exact reading, and entered in the log book or observation book.

Position of a Barometer.—A barometer, unlike a thermometer, *must be exposed as little as possible to changes of temperature.* The justness of the temperature correction (the necessity of which is explained in page 32-33) depends upon all parts of the instrument having the same temperature as that shown by its attached thermometer. But the mercurial column is enclosed in a glass tube, a bad conductor of heat, and this again usually in a metal tube with an air space between. Consequently, the mercury is slow in acquiring or parting with heat, and it is only by keeping the temperature around as uniform as possible that the required conditions are even approximately fulfilled. *A barometer should therefore be kept in a well-enclosed room, and the sun must never shine on it, nor must it be near a fire-place, steam pipe, or other source of heat.*

The second point to be attended to is to obtain a good light, since the accuracy with which the instrument may be read depends on the lighting.

The source of light should be either on the right or left hand (not at the back, and still less opposite the barometer), and a white surface, well illumined, should be provided behind the upper part of the tube, to facilitate the accurate adjustment of the mercury level and the vernier.

For marine and other barometers, small card-clips the form of which is shown in (fig. 16) are now constructed at the Mathematical Instrument Manufactory in Calcutta, which can be attached to the instrument, with a clean white card C inserted. This is the best kind of reflector that can be employed. It is adjusted somewhat more obliquely than is shown in this figure, so as to reflect the light from the right or left of the instrument.

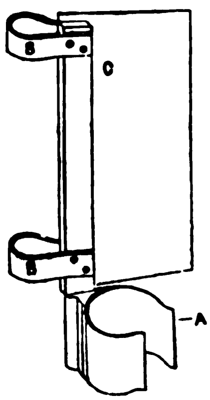


Fig. 16.

It is also desirable to note as a general rule that a barometer should never be moved from the place it has habitually occupied, unless such removal is absolutely unavoidable.

Tests of good condition of a Barometer.—When a marine barometer is in good order, if it be slowly inclined until the mercury reaches the top of the tube, it gives a sharp click at the instant of contact. If the barometer fails to do this there is air in the upper part of the tube above the mercury column, and the barometer should be either repaired by a proper instrument-maker or be replaced by another. The surface of the mercury against the tube should be bright and there should be no visible air-bubbles. If the surface of the mercury be dull, it is probable that there is a thin film of air clinging to the glass. Air-bubbles, or a film of air, do not affect the readings so long as they are below the top of the column, but the air tends to move slowly upwards and to pass into the upper part of the tube above the column, and thus spoil the barometer for accurate measurement. In some barometers a special arrangement called an "air trap" is used, by which the rise of air along the surface of the glass in the tube beyond a certain point below the top of the column is prevented, and it is desirable in purchasing a good barometer to ascertain that it is provided with such an air-trap.

Necessity for occasional comparison with a standard barometer (e.g. the Calcutta Standard Barometer).—All barometric observations in the Government observatories in India are determined or taken from barometers which have been directly or indirectly compared with the Calcutta standard, and all means, &c., given in this book are referred to that standard. As already pointed out, the necessity of such a comparison with a standard instrument is theoretically as great as is the comparison of a chronometer with a standard indicator of time,—as, for example, the dropping of a time-ball, or the firing of a gun, which is regulated by a standard clock made to keep standard time. The necessity of these comparisons depends upon the fact of the imperfection of human workmanship, so that it is utterly impossible to obtain two instruments which shall give exactly the same indications under the same circumstances. Fortunately, in the case of good mercurial barometers, constructed by such makers as Casella, Negretti and Zamhra, Adie, Hicks, Browning, &c., it is not necessary that the comparison should be made frequently so long as the instrument is in good working order. Many of the barometers used in India have been found not to alter their errors sensibly for periods of from four to ten or twelve years. A

very occasional comparison with a standard instrument would therefore be sufficient for all practical purposes, and if the captains of vessels contributing meteorological logs to the records of the Bengal or India Meteorological Office expressed generally a desire to have the errors of their barometers ascertained with reference to the Calcutta standard for their own use, either of these offices would be very willing to make arrangements to do it free of charge. The extended use of compared barometers on board ship, it is hardly necessary to say, would make the information sent in by captains of vessels to the Meteorological Office of much greater value than it is at present. The necessity of this, I may add, is strongly shown by the character of the barometric observations taken on board ships during cyclonic storms sent in to the Meteorological Office in reply to its request for such information. Many of the observations which have been contributed could not be utilized at all, in some cases because the barometers were evidently out of order, and in other cases because there were large errors in the instruments and there were no means of ascertaining the exact amounts. I have come across such readings where the barometer evidently read two or three tenths too high, and in others as much as four or six tenths too low. Aneroids (by good makers) which have been tested at Alipore in a vacuum chamber have been found to vary from two tenths of an inch to three inches at different parts of their scale from the reading of a standard mercurial barometer placed in the same chamber, and mercurial barometers of cheap and common types have been similarly found to have index errors of one to five tenths of an inch.

The great majority of sailors in using the barometer confine themselves to reading the height of the barometer and the temperature of the mercury as indicated by the attached thermometer. If the observations are to be used for accurate comparison, it is necessary to allow for change of temperature. The reason for this is explained below and the methods of allowing for it are given in the following paragraphs.

Correction of the Barometric height for Temperature.—The pressure of the air is measured by the height of a column of mercury. But the same pressure of the air may correspond to different heights of the mercurial column, which of course lengthens if it be heated. Hence simply increasing the temperature of the mercury causes it to stand or read higher. For example, suppose that a barometer was suspended in an open shed during the hot weather in Upper India, such as, in fact, is used for suspending the thermometers in order to find the temperature of the air in the open. The temperature of the air and the mercury in the barometer might probably be as much as 120°. Suppose the reading of the barometer then was 29·8 inches. If the barometer were taken into a room cooled by means of thermantidotes, and where the temperature was, say, 84°, the barometer would immediately begin to fall and continue to fall until the mercury acquired the temperature of the room (84°) and would there stand at about 29·7 inches. The pressure of the air would have remained unchanged during this time. Hence the same pressure would be measured by a barometric height of 29·8 inches when the temperature of the mercury was at 120°, and by a barometric height of 29·7 inches when its temperature was 84°, a difference of one tenth of an inch in the height of the

barometric column, due solely to change of temperature of the mercury. Hence it is necessary, not merely to observe the height of the column of mercury, but also its temperature. It would, however, be very inconvenient to have to take into account at the same time the temperature, as well as the height, of the mercury in making comparisons. The meteorologist gets over this difficulty by adopting a standard temperature for the comparison of barometric readings. The actual reading (or height of the barometer) at the given temperature is by calculation reduced to the height that the mercury would stand at if its temperature were changed to that of the standard temperature. This is of course a much simpler and quicker method than that of actually warming or cooling the mercury until it actually acquired the fixed or standard temperature, just as it is much easier to allow for the *error* or rate of the chronometer so as to obtain from its reading Greenwich *mean time*, than it would be to be frequently moving the regulator so as to make it keep exact Greenwich mean time. The standard temperature which has been *arbitrarily* fixed upon by meteorologists is the freezing point of water (32° F.) and the process of allowing for this difference of the actual temperature from the temperature of freezing water is usually called "reducing the barometric reading to temperature 32° F." Hence every good mercurial barometer has a thermometer attached to it, which gives (if properly placed) the temperature of the mercury in the instrument (and not of the outside air). If the height of the equivalent column at the fixed temperature 32° be required, it is necessary to apply a correction to the actual reading depending on the actual temperature of the mercury, so as to give the height of an equivalent column at the fixed temperature 32°. The pressure of the air is in all cases exactly proportional to the height of the corrected barometric column or the reduced barometric reading and the changes of the reduced barometric readings are strictly proportional to the changes of the pressure of the air, and can therefore be taken as a correct and reliable measure (referred to a fixed and unchanging standard) of the changes of pressure. This is what is always done in meteorological offices, and should be done by all using the barometer in Indian seas. The following table gives the corrections which should be used to reduce the reading of the barometer at any temperature, such as is likely to be experienced in the Bay of Bengal, to the fixed temperature 32° F.

When the temperature of the attached thermometer is—

between	61°—64°	subtract	·09″	in order to give the reading reduced to 32° F.		
"	65°—68°	"	·10″	"	"	"
"	69°—72°	"	·11″	"	"	"
"	73°—76°	"	·12″	"	"	"
"	77°—80°	"	·13″	"	"	"
"	81°—84°	"	·14″	"	"	"
"	84°—88°	"	·15″	"	"	"
"	88°—92°	"	·16″	"	"	"
"	92°—96°	"	·17″	"	"	"
"	96°—100°	"	·18″	"	"	"

The preceding table explains itself. The following states the method of its use. Suppose the reading of the barometer on board a ship in the north of the Bay on a given day is 30·12″, and that of the attached thermometer is 70°. Then the table shows that for this temperature (for 69° to 72°) ·11″ is to be subtracted. Hence ·11″ taken away from 30·12″ leaves 30·01″, which is the

barometric reading reduced to 32°. Similarly, if in the centre of a cyclonic storm in the Bay the actual readings of the barometer and attached thermometer were 27·65″ and 84°, the correction corresponding to 84° is ·15″, and the reduced reading would be 27·65″ less ·15″ or 27·50″. The pressure of the air at the centre would be proportional to 27·50.

Correction to reduce the Barometer to sea-level.—There is one other correction which meteorologists dealing with observations taken at land observatories are obliged to make, but which does not practically concern mariners. It is well known that the barometric height at the same place decreases if the barometer be taken up above the earth's surface. Hence it would be manifestly practically useless to compare the barometric heights at two places at different levels above the sea, without making due allowance for their difference of height above mean sea-level. It is therefore necessary to reduce the reading of the barometer in all cases where exact comparisons have to be made, to what it would be if the height of the barometer were an actual fixed amount. This is always done by referring it to the sea-level. The allowance thus made for the elevation of the barometer at any place above the sea-level is called the reduction of the barometer to sea-level, and the modified reading of the barometer —*the barometric height reduced to sea-level.* The correction applied to reduce the barometer to sea-level is usually termed "correction to sea-level," and as increase of elevation causes the column to fall, the correction will evidently be additive. Where the height does not exceed a few hundred feet the following rule is sufficiently exact:—

To make the correction to reduce the height to sea-level, add one hundredth of an inch for every eleven feet of elevation above the sea-level.

As, however, it is only necessary that mariners should read their mercurial barometers to one hundredth of an inch, and as barometers on board ships are not actually more than a few feet above mean sea-level, it is not necessary for them to make this correction.

The preceding paragraphs have shown that if sailors wish to make the fullest and best use of their barometric observations, they should, at the time of taking and entering the readings in their log books, make the following two corrections to every reading of the barometer:—

(1) The correction for the permanent error (or difference from the standard) of their barometer.

(2) A correction to reduce the reading at the actual temperature of the mercury to the standard temperature (32° F. or the freezing point of water).

Thus, suppose that the barometer reads 29·75″ and the attached thermometer 84°, and the correction for the error of the particular instrument known to be +·06″ (that is ·06 is to be added) to the standard barometer (Calcutta for example), the following would be the calculation to find the corrected reading to be used for purposes of comparison worked out fully:—

Actual barometric reading	29·75″
Correction for error of instrument	+·06
Reading corrected for first error	29·81″
Correction for temperature 84° (see page 33)	—·14
Reading corrected for error and for temperature	29·67″

The corrected readings should be duly entered in the log book. It is those readings only which any person can fairly and properly use if he wishes to compare these barometric readings with those at any other place or time. If these corrections are not made, the readings are isolated and cannot be compared with others, as they have no common standard of reference. He might as well employ his own watch to time his chronometers or use an unrated chronometer to determine his longitude. When the sailor has learnt to reduce his barometric observations to a common standard and to the fixed temperature usually adopted, he is then (and not before) in a position to compare his barometric readings with others.

Methods of barometric comparison.—The meteorologist, sitting in his office and in telegraphic communication with his observatories, makes three sets of comparisons daily, in order that he may determine when storms have formed and are approaching any portion of the coast to which he gives storm warnings and hoists storm signals.

He first of all compares the observations taken at different stations at the same hour and day, and is thus able to ascertain the differences of the air pressure as given by the readings of the barometer (reduced for temperature and to sea-level) at different stations, and compares these readings and differences and the other weather conditions prevailing at that hour at the various observing stations in the area with which he deals. This kind and class of comparison is not practicable for the mariner so long as he is at sea.

The meteorologist, in the second place, compares the observations of a given day and hour with the normal, or average, values of the same element of observation for the period at the given place as determined by long-continued observation. This enables him to ascertain how far the weather conditions of the day differ from those proper to the day. By this comparison for all the places from which he receives his observations he is able to infer with approximate certainty the immediate consequences of the variations of the weather conditions from the normal, and to ascertain, for example, from these facts and the actual wind and other observations, the position, extent, and intensity of cyclonic storms,—and to forecast their probable line of march and changes (either of increase or decrease, &c.) of size or intensity with approximate accuracy. This second mode of comparison is open to the sailor to a limited extent, and it is one of great advantage in India and the Bay of Bengal, where the great majority of the weather-changes occur with a regularity and smoothness utterly unknown in temperate regions.

In the third place, the meteorologist compares the observations of the day with those taken at the same hour on the previous day, and thus learns what changes have taken place during the interval at each of the reporting stations. This third method of comparison is also open to sailors on board ships, provided they are sailing or steaming so slowly that the changes recorded by the barometer are not due to change of position, but only to the actual variations or changes in progress in that part of the Bay, or that they make allowance for change in the height of the barometer due to mere change of position. It should for such a comparison of course be carefully remembered that, at certain seasons of the year, the barometer stands at very different heights in different parts of the Bay, and hence that the mere change of position of a vessel will cause the barometer

to rise or fall according as the ship is advancing in one direction or the opposite. Thus, in the height of the south-west monsoon in the Bay, the barometer on board a ship proceeding northwards from the entrance to the head of the Bay should, by mere change of position, fall from three to four tenths of an inch in ordinary weather, and as much as five or six tenths if a very strong monsoon be blowing.

It is hence very desirable that sailors should make, so far as is possible, similar comparisons, and thus use the barometer to the fullest advantage. The second mode of comparison is the easiest to make by sailors, and it is the one which on the whole gives the most valuable information. It is hence desirable to explain fully the simplest method of comparing the actual barometric reading on any given day with the normal reading of the period at the given place. In order to make the comparison, it is necessary that the normal barometric height at the place and time of observation should be known. This is most easily done by means of charts, as will be presently explained. Unfortunately the great majority of charts published by meteorological departments, including the very valuable series giving meteorological data for the Bay of Bengal and Arabian Sea, prepared by Mr. Dallas, Assistant Meteorological Reporter to the Government of India, give the mean pressure of the day, and not the average or normal pressure at a particular hour of the day. In order to determine the mean pressure of the day, it is necessary to take a number of readings of the barometer at equal intervals—six-hourly, four-hourly, &c., and take the mean of all these,—*i.e.* add the various observations of one day together and divide by the number of observations taken during the day. This is a slow and laborious comparison, and it is probably one which will gradually become, except in very special cases, obsolete, even in meteorological offices, for such comparisons as are here suggested. The best and simplest comparison is that between the actual barometric reading or height at a given hour and the average or normal barometric height at the same place for the same hour of the same period of the year, as determined by a very large number of observations made during many years, and it is this comparison which any captain can make in two or three minutes by the use of the charts given in the present book.

Hours of observation.—It is hence necessary for the purpose of exact comparison to fix upon a certain hour or hours of the day for making meteorological observations and comparisons, and to take the observations at the exact local time fixed upon. This is of course always possible on land, but at sea, as the clocks are adjusted to local time at intermittent intervals, there is always a possibility of an error of several minutes in the time,—that is, 8 A.M. as indicated by the clock may not be exactly 8 A.M. local time, but may be 7-45 or 8-15 A.M.

The best hours for observation of the barometer in India and the Bay of Bengal are undoubtedly 4 A.M., 10 A.M., 4 P.M., and 10 P.M. The barometer is either at its highest or lowest at these hours, and for a little time before or after it moves so very slowly in ordinary weather as to be practically steady. An error of a few minutes, or even a quarter of an hour, in the time hence makes practically no difference in the reading of the barometer, and therefore exactness of time in making the observation is not necessary.

On the other hand, the barometer falls rapidly during the day from about 11 A.M. to 2 P.M., and an error of a few minutes in the time makes an appreciable difference in the height of the barometer. Hence, if the barometer be read at noon with the intention of comparing it with the normal barometric height at noon, considerable accuracy of time would be necessary.

Previously to April 1888 observations were taken at all observatories in India at 10 A.M. and 4 P.M., but these hours were found to be very inconvenient for the preparation of the daily weather reports, based on the daily weather telegrams, transmitted by the various observatories. It was decided to try experimentally for a few months the same hour for the morning observations as has been fixed in England and other European countries, *viz.* 8 A.M., with a view to its final adoption as the chief hour of observation in India. It was found to work very successfully, and enabled the Department to issue the various daily weather reports published at Simla, Calcutta, and Bombay, much earlier in the day than had been previously possible, and to hoist storm signals earlier than hitherto and thus give longer notice before the approach of cyclonic storms. 8 A.M has hence been finally adopted as the chief hour (and in some cases the only hour) of observation at all the observatories in India. This change will make the meteorological observations obtained from ships of much greater value than hitherto, for 8 A.M. is one of the hours at which the barometer, wind direction and force, are recorded in the logs of ships, and it would hence be extremely desirable that ship-masters in Indian seas should make that hour the chief hour of meteorological observation, and of comparison of the actual barometric or pressure condition of the day with the normal, as shown by the charts that have been drawn up for this purpose and are given at the end of the book.

In these charts 8 A.M. has consequently been adopted as the general hour for the registration of the height of the barometer and for the ordinary comparison of the actual reading with the normal value, suggested above. The charts (Plates III to XVI) give the normal pressure at that hour for every month in the Bay of Bengal.

Explanation of the Charts giving the 8 a.m. mean pressure or height of the Barometer and the mean winds for different months in the Bay.—The charts of mean pressure and wind direction given at the end of the book (Plates III to XVI) are drawn up with the object of showing at a glance the ordinary or normal height of the barometer in the Bay of Bengal during the different months of the year. The height of the barometer as given in these charts is the height corrected for temperature, &c., as explained on page 34. The charts are given for each month during the year, except for the months of May and September. During these two months pressure in the Bay changes rapidly, and hence it has been considered advisable to give two charts for each of these months, one for each half of the month, as well as the charts for the month. We strongly advise the use of the charts of the half months in these cases for comparison, and not the charts for the month. The latter are given in order to make the series of monthly charts complete.

On each of these charts curved lines of equal pressure, or *isobars* as they are usually termed, are drawn at unequal intervals. These curved lines, or isobars, play exactly the same part with respect to air pressure or barometric height

that the parallels of latitude do with respect to place or position on the earth's surface. Each line runs through all places having the same ordinary or normal pressure at that period, just as a parallel of latitude runs through all places at the same distance from the equator. A number is placed near each line denoting the barometric height,—for example, 29·95″, 29·90″.

Several lines are drawn on each chart for equal differences of pressure of ·05″, or five hundredths of an inch. Hence, in passing from a place on one line to a position on the next line to the north or south, the barometer (read at 8 A.M.) would usually rise or fall ·05″ in the month for which these lines are given.

Also, as the changes of pressure in going up or down the Bay are gradual, it is evident that the charts not only give the pressure at places or positions on the lines of equal pressure or isobars, but also in any intermediate position, just as the position of any place on the earth's surface (*i.e.* its latitude and longitude) can be ascertained from the lines of latitude and longitude drawn at regular intervals on a chart when the position of the place is shown on the chart. In either case all that is required is to allow a proportional amount for the distance of the place from the next nearest line as compared with the distance of the two *isobars* between which the place or position is situated. Thus, to find the mean or ordinary 8 A.M. height of the barometer at any place not on any isobar, find the shortest distance between the two consecutive isobars within which it lies, through the given place, and also find its distance from the nearest isobar. Then, as the former distance (corresponding to a difference of pressure of ·05″) is to the latter, so is ·05″ to the actual difference of pressure between that at the given place and that at the nearest isobar. Thus, supposing in the month of May, along the meridian of 88° E., pressure falls from 29·82″ in Lat. 15° N. to 29·77″ in Lat. 19° N., and that it is required to find the pressure or barometric height in Lat. 16½° N. in the same meridian—

	Change of pressure for	4° is ·05″
∴	" "	1° " ·0125″
and	" "	½° " ·0062″

whence change for 1½° is ·0187″, or ·02″ nearly.

Hence in proceeding from Lat. 15° to Lat. 16½° N., the barometer (read at 8 A.M.) should under ordinary circumstances fall from 29·82″ to 29·82″ less ·02″, or 29·80″.

It will be evident to a sailor that the calculations can be made more quickly and easily by the use of compasses and scale than by a rule of three question, and that the results will be accurate enough for all practical purposes.

When the reader has learnt to find from these charts the mean or ordinary 8 A.M. pressure or barometric height for any month or period, he can, by the use of the method explained on page 41, find the ordinary pressure at any other hour of the day. All that is required is for him to apply in the manner there stated the number opposite to the given hour to the 8 A.M. pressure as above determined, and the sum or difference will give him the reading at that hour. When the sailor has learnt to find the ordinary or mean 8 A.M. pressure at any season of the year at any position in the Bay, he can at once, by taking the difference be tween this number and the actual 8 A.M. height of his barometer (corrected for temperature, &c., as previously explained), find exactly how much the actual

pressure of the air or barometer differs from the ordinary or normal pressure,—that is, the pressure which obtains during the ordinary weather of the season. This will, as we shall show in a future section, furnish him with a most valuable indication for forecasting weather, and assist him in deciding whether he is approaching a cyclonic storm.

The mariner should at least once a day (at 8 A.M.) make the comparison here suggested; and if the weather becomes threatening, he should make it at intervals of a few hours.

I would hence strongly urge sailors to have three columns instead of one or two, as is at present the usual arrangement, in their meteorological logs for the record of pressure. In the first would be given the reading of the barometer (corrected for temperature, &c., as explained in page 34); in the second, the ordinary, or normal, reading of the barometer for the season as determined from the charts in the manner explained above; and in the third column, the difference between these two, showing whether the actual reading is above or below the normal, and by how much. With a little practice the whole calculation would not require more than five minutes, and the mariner would be amply repaid for the labour by the additional information it would give him.

The following examples and results are given which the reader can for practice verify:—

Mean 8 A.M. pressure in position	Latitude 10° N.,	Longitude 84° E.		in month of June .	29·81"
Ditto	do.	do.	do.	in month of July .	29·83"
Ditto	do.	do.	do.	in month of August	29·85"
Ditto	do.	do.	do.	in first fortnight of September .	29·88"
Ditto	do.	do.	do.	in second do. .	29·90"
Ditto	do.	do.	do.	in month of October	29·91"
Ditto	do.	do.	do.	in month of November	29·96"
Mean 8 A.M. pressure in position	Latitude 16° N.,	Longitude 88° E.		in month of June .	29·72"
Ditto	do.	do.	do.	in month of July .	29·72"
Ditto	do.	do.	do.	in month of August	29·76"
Ditto	do	do.	do.	in first fortnight of September .	29·80"
Ditto	do.	do.	do.	in second do. .	29·84"
Ditto	do.	do.	do.	in month of October	29·87"
Ditto	do.	do.	do.	in month of November	29·99"

Diurnal oscillation of the Barometer.—If the mariner wishes to compare his barometric reading at any other hour than 8 A.M. with the mean, or normal, barometric height, he must make allowance for the changes of the height of the barometer due to what are termed the daily tides or diurnal oscillation.

The atmospheric tides, as shown by the barometer in the tropical regions, and hence in the Bay of Bengal, go on with a regularity as marked as the oceanic tides. Moreover, as they depend on the sun only, and not upon the double action of two bodies, the sun and moon (whose position with respect to each other varies from day to day), the atmospheric tides are much simpler and steadier than the oceanic tides. There are two tides, waves, or oscillations daily, exactly as in the case of the ocean. The highest pressures due to these atmospheric tides, corresponding to high water, occur at about 10 A.M. and 10 P.M., and the lowest pressures at 4 P.M. and 4 A.M. They are hence separated by six-hour intervals (of solar time). There is no such phenomenon in these

tides as in the oceanic tides of spring and neap tides. There are slight differences between the diurnal rise and fall of the barometer or the height of the tide from one season of the year to another. This is of course due to the fact that the sun's action on the atmosphere varies slightly with its elevation and its varying distance from the earth.

And here it is as well to notice that the analogy with the oceanic tides must not be carried too far. There are many who picture to themselves the air as extending to a certain height above the earth's surface and terminating at a surface as definite as that of water, and also imagine the height of this surface alters with the diurnal tides, &c., just as the surface of the sea does by the action of the tidal wave. This is almost certainly not the case. All that we know of gases show that if they are not shut in they tend to expand indefinitely. It is possible that there are air-particles scattered throughout the whole of space, although scientific opinion is divided on that point. It is certain that they are only condensed or packed closely together near the surfaces of the heavenly bodies, and thus form what are called the atmospheres of those planets.

The differences in the height of the barometric oscillations or daily tides from month to month or season to season in the Bay of Bengal are so small that the following table and results may be assumed to be true for the whole year. The quantities are given in hundredths of an inch and are the differences between the average reading of the barometer at 8 A.M. and at the various hours specified in the first column :—

Table of corrections to reduce the mean barometric pressure at 8 a.m. in any part of the Bay of Bengal to that of any other hour of the day.

Hour.	Correction to be applied.
Midnight .	—·02 or two hundredths to be subtracted.
1 A.M. .	—·04 „ four „ „
2 „ .	—·05 „ five „ „
3 „ .	—·06 „ six „ „
4 „ .	—·06 „ six „ „
5 „ .	—·05 „ five „ „
6 „ .	—·04 „ four „ „
7 „ .	—·02 „ two „ „
8 „ .	*Nil*—no correction.
9 „ .	+·01 or one hundredth to be added.
10 „ .	+·01 „ one „ „
11 „ .	*Nil*—no correction.
Noon .	—·02 or two hundredths to be subtracted.
1 P.M. .	—·04 „ four „ „
2 „ .	—·06 „ six „ „
3 „ .	—·07 „ seven „ „
4 „ .	—·08 „ eight „ „
5 „ .	—·07 „ seven „ „
6 „ .	—·06 „ six „ „
7 „ .	—·04 „ four „ „
8 „ .	—·02 „ two „ „
9 „ .	—·01 „ one „ „
10 „ .	—·01 „ one „ „
11 „ .	*Nil*—no correction.
Midnight .	—·02 or two hundredths to be subtracted.

The use of this table is very simple. Suppose that the mean barometric height for any other hour than 8 A.M. is required at any time of the year. Look the out number opposite to the hour and subtract it from, or add it to, the mean barometric height of the place for the period or month according to the instructions given in the table. Thus, if the 8 A.M. mean barometric height in Lat. 18° N., Long. 88° E., in the month of October is 29·63″, and it is wished to find the mean barometric height at, say, 3 P.M., opposite 3 P.M. in the table is —·07, or ·07 to be subtracted. Hence, subtracting ·07″ from 29·63″ gives 29·56″, the mean barometric height at the same place at 3 P.M. And if the actual reading of the barometer at that place at 3 P.M. on any day in October, when corrected for the error of the instrument and for temperature, was 29·34″, the barometer would be ·22″ lower than it would ordinarily be in fine weather at that hour in the month of October, and almost certainly be due to, and indicate the existence of, a cyclonic storm in some part of the Bay, the position of which could be determined roughly from the wind direction.

As the diurnal tides, or oscillation of the barometer in the Bay of Bengal are of great interest and importance to mariners, as well as to meteorologists, the following more exact data, which have been calculated from a very large number of observations taken on board ships in the Bay, are given for reference:—

Hourly values of the Variation of Pressure.

	Lat. 0°–10°. Long. 80°–90°.	Lat. 10°–20°. Long. 80°–90°.	Lat. 0°–10°. Long. 90°–100°.	Lat. 10°–20°. Long. 90°–100°.	Annual mean for the Bay.
Midnight	+ ·0102	+ ·0083	+ ·0137	+ ·0084	+ ·0102
1	— ·0056	— ·0069	— ·0020	— ·0062	— ·0052
2	— ·0196	— ·0214	— ·0175	— ·0201	— ·0197
3	— ·0275	— ·0300	— ·0272	— ·0285	— ·0283
4	— ·0264	— ·0296	— ·0280	— ·0283	— ·0281
5	— ·0164	— ·0193	— ·0189	— ·0188	— ·0184
6	+ ·0004	— ·0016	— ·0022	— ·0022	— ·0014
7	+ ·0194	+ ·0188	+ ·0172	+ ·0172	+ ·0182
8	+ ·0355	+ ·0365	+ ·0338	+ ·0343	+ ·0350
9	+ ·0441	+ ·0465	+ ·0426	+ ·0443	+ ·0444
10	+ ·0427	+ ·0462	+ ·0413	+ ·0447	+ ·0437
11	+ ·0313	+ ·0359	+ ·0303	+ ·0353	+ ·0332
Noon	+ ·0125	+ ·0182	+ ·0125	+ ·0184	+ ·0154
13	— ·0093	— ·0026	— ·0077	— ·0018	— ·0054
14	— ·0289	— ·0216	— ·0255	— ·0207	— ·0242
15	— ·0416	— ·0349	— ·0375	— ·0341	— ·0370
16	— ·0447	— ·0399	— ·0412	— ·0394	— ·0413
17	— ·0379	— ·0361	— ·0362	— ·0358	— ·0365
18	— ·0231	— ·0249	— ·0240	— ·0247	— ·0242
19	— ·0046	— ·0093	— ·0075	— ·0092	— ·0077
20	+ ·0130	+ ·0065	+ ·0092	+ ·0065	+ ·0088
21	+ ·0249	+ ·0184	+ ·0222	+ ·0183	+ ·0210
22	+ ·0284	+ ·0233	+ ·0279	+ ·0229	+ ·0256
23	+ ·0229	+ ·0195	+ ·0247	+ ·0193	+ ·0216

These figures give the difference between the mean pressure of the day and the mean pressure of each hour of the day, and hence necessarily differ slightly from those given in the preceding page. They show that the actual readings of the barometer at 1 A.M., 6 A.M., 1 P.M., and 7 P.M. very nearly agree in ordinary

fine weather (that is when there are no unusual barometric movements in progress due to storms) with the mean pressure of the day. In the plates (I and II) given at the end of the book these numbers are charted in such a way as to show at once the actual character of the barometric movement due to the diurnal oscillations of pressure. The numbers, and hence the curves, differ slightly for different parts of the Bay. The first curve gives the mean diurnal oscillation between Lat. 0° and 10° N., and Long. 80° and 90° E.; the second between Lat. 10° and 20° N., and Long. 80° and 90° E.; the third between Lat. 0° and 10° N., and Long. 90° and 100° E.; and the fourth between Lat. 10° and 20° N., and Long. 90° and 100° E. The last curve (fig. 5) gives the mean diurnal oscillation for the whole of the Bay and is practically that upon which the figures given in page 41 are based.

It may be noted that these figures and curves have been obtained from a very large number of observations taken on board ships in the Bay of Bengal during the years 1859 to 1878 and collected by the London Meteorological Office.

A glance at the last curve will enable any one to ascertain all the more important features of the diurnal oscillation in different parts of the Bay. It shows the double character of the oscillation, and that the day tide is a larger one (or causes a greater rise and fall of the barometer) than the night tide. The first four curves also indicate that the night tide is somewhat larger in the south of the Bay than in the north. It may be added that the causes of these tides are as yet but imperfectly understood, although there can be no doubt of the general fact that they are due to the action of the sun on the atmosphere, and that their regularity in the tropics is the result partly of the greater intensity of the action of the sun in the tropics, and partly to the very slight changes in the length of day and night during the year in the tropics, so that the sun acts with great regularity and uniformity the whole year round on the tropical atmosphere.

General character of the larger barometric changes in the Bay of Bengal.—It has been pointed out in the preceding paragraphs in what manner the barometer should be observed in the Bay of Bengal by those who wish to use its indications to the fullest extent, and in what manner comparisons may be made with the object of ascertaining at any time whether the actual barometric readings of the air pressure are above or below those proper to the season and by how much. If the observations be taken in the manner suggested, the mariner will find that the following principles or rules, which have been derived mainly from the observations taken at the coast stations of the Bay, hold equally for the Bay itself. These principles are fully stated, explained, and illustrated in the following paragraphs.

(*A*) *Except during the existence of the larger and more severe cyclones the barometric changes in the Bay of Bengal are always small in amount and take place very steadily and gradually.* There is none of that rapid and large fluctuation of the barometer in the Bay of Bengal such as occurs in England or the North Atlantic Ocean if the weather be the slightest unsettled. A fall of a tenth of an inch in 24 hours in any part of the Bay is certainly less frequent than a

fall of half an inch, and probably less frequent over the greater part of the Bay than a fall of an inch, in the same interval in England or the British Seas. The first table which follows gives the number of times in the five years 1883-87* when a fall of more than a tenth of an inch in 24 hours occurred at the coast stations of Port Blair, Diamond Island, Akyab, Chittagong, Saugor Island, Gopalpore, Coconada, Madras, Negapatam and Trincomalee; and the second table the number of times a rise of more than a tenth of an inch occurred during the same period—

Stations.	Number of times during the five years 1883-87 in which the barometer fell in 24 hours between				
	One and two tenths.	Two and three tenths.	Three and four tenths.	Four and five tenths.	Over five tenths.
Port Blair	7	...	...	...	...
Diamond Island	13	...	...	...	...
Akyab	18	1	...	...	...
Chittagong	17	1	...	...	...
Saugor Island	27	2	...	...	...
Gopalpore	8	...	...	...	...
Cocanada	4	...	...	...	...
Madras	4	3	...	...	...
Negapatam	1	...	...	...	...
Trincomalee	4	...	...	...	...
Total for Stations	103	7	...	...	...

Stations.	Number of times during the five years 1883-87 in which the barometer rose in 24 hours between				
	One and two tenths.	Two and three tenths.	Three and four tenths.	Four and five tenths.	Over five tenths.
Port Blair	2	...	...	...	...
Diamond Island	9	...	...	...	...
Akyab	24	2	...	...	...
Chittagong	18	3	...	...	...
Saugor Island	33	2	2	...	...
Gopalpore	16	1	...	...	...
Cocanada	10	...	...	...	...
Madras	6	1	...	1	...
Negapatam	3	...	...	...	...
Trincomalee	3	...	...	...	...
Total for Stations	124	9	2	1	...

The preceding tables show that a rise of one tenth of an inch is somewhat more frequent than a fall of the same amount. This is only in accordance with the general principle that in cyclonic disturbances the barometer usually rises more quickly in the rear of the storm than it falls in front.

* For the eight months May to December.

(*B*) *An equally important feature in which the changes of pressure in the Bay of Bengal differ from those usually experienced in the British seas or temperate regions is, that there are large regular movements of the barometer which have absolutely nothing to do with stormy or disturbed weather, and which consequently must be allowed for before we can obtain the changes of pressure caused by approaching bad weather or by a cyclonic storm.* One of these is the daily tides or diurnal motion of the mercury in the barometer which goes on with the same regularity in fine as in unsettled weather. It is a kind of pulsation or oscillation which continues amidst all the changes and variations of weather in India, and is performed with such regularity that if it were not that it is occasionally mixed up with, and obscured by, other changes, it might be used to determine the time of day approximately. As this movement goes on equally in fine as in stormy weather, it can have nothing to do with the production of the latter, and hence this regular change must be left out of account entirely in using the barometer as an indicator of stormy weather.

Again, in the months of June, July, and August, when the south-west monsoon is fully established, there is always a difference of pressure, averaging nearly four tenths of an inch, between the south and the head of the Bay. Hence the barometer on board a steamer going up the Bay from Galle to Calcutta will usually fall during the three or four days of the passage four tenths of an inch in consequence of the ordinary weather conditions of the period. A smaller fall than this would probably mean much finer weather than usual, and a larger fall that a very strong monsoon was blowing over the whole of the Bay, or a cyclonic storm was in progress near the head of the Bay.

It may also be noted that even after due allowance is made for the daily oscillation, it is found that the atmospheric pressure or the height of the barometer is never absolutely steady, but, like the bob of a pendulum suspended by a long wire or string, is always moving or oscillating through small distances. Thus, in the finest and most settled weather in India, the barometer rises for a short period, usually about one to three days, and then falls for a similar period and rises again, and so on. These small oscillations appear to be almost as essential a part of the ordinary atmospheric changes as the diurnal tides, and hence are almost independent of the weather. By far the larger number of disturbances, however, appear to originate during the periods of falling barometer, and hence, as might be expected *a priori*, the unsettled weather, which precedes cyclonic storms, tends to occur during the falling, rather than the rising, portion of these general barometric movements or oscillations over India.

(*C*) *The barometric changes are, as a rule, much smaller in the south than in the centre and north of the Bay.* For the barometer at the entrance of the Bay in ordinary weather does not vary more than two tenths of an inch all the year round, rising and falling between 29·85″ and 30·05″ (leaving out of account the daily barometric tides). Whereas in the north of the Bay (without taking into account the large movements during cyclonic storms) the barometer falls from an average of 30·20″ in January to an average of 29·50″ in July, or

through seven-tenths of an inch. Hence the total annual range or movement of the barometer is very small in the south of the Bay and increases in amount northwards.

(*D*) *The barometer in the Bay of Bengal during the period, May to November and December, to which cyclonic storms are almost entirely confined, seldom falls so much as a tenth of an inch, and very rarely so much as ·15 inch in 24 hours at the same place unless a cyclonic storm is forming in the neighbourhood of, or is advancing towards, the place of observation.* This is practically proved by the experience of the past ten years. A portion of the evidence is summarized in the tables given below. On the assumption of the truth of this principle and of principle (*C*), it is evident that a fall of a tenth of an inch in 24 hours in the centre or south of the Bay is even a more certain indication of cyclonic or stormy weather near the place of observation than in the north of the Bay.

The following gives data for five years in the case of thirteen coast stations round the Bay of Bengal in proof of this statement:—

Stations.	1883.		1884.		1885.		1886.		1887.		Total.	
	Number of times when barometer fell between ·1″ & ·15″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·1″ & ·15″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·1″ & ·15″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·1″ & ·15″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·1″ & ·15″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·1″ & ·15″.	Number of falls due to cyclonic storm.
Port Blair	...	...	1	1	...	...	3	1	1	1	5	3
Diamond Island	3	2	1	1	1	...	4	1	2	1	11	5
Akyab	3	3	3	3	5	3	3	...	2	2	16	11
Chittagong	2	2	4	3	2	2	7	1	1	1	16	9
Saugor Island	7	5	2	2	4	3	5	2	6	5	24	17
False Point	5	4	2	1	2	1	4	2	5	4	18	12
Gopalpur	...	...	3	2	1	1	2	1	2	1	8	5
Vizagapatam	1	1	1	...	...	...	3	3	1	1	6	5
Cocanada	1	1	...	...	...	...	1	1	1	1	3	3
Masulipatam	...	...	1	...	2	2	1	1	1	1	5	4
Madras	...	...	...	...	...	...	1	1	...	...	1	1
Negapatam	...	...	...	...	...	...	1	1	...	...	1	1
Trincomalee	...	...	...	...	3	2	1	...	...	...	4	2
Total for all Stations	22	18	18	13	20	14	36	15	22	18	118	78

The preceding table shows that in the case of the selected stations and period the barometer fell on 118 occasions more than a tenth of an inch, and on

78 of these occasions (or practically in two out of three) the fall occurred during the approach of a cyclonic storm.

Stations.	1883.		1884.		1885.		1886.		1887.		Total.	
	Number of times when barometer fell between ·15″ & ·20″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·15″ & ·20″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·15″ & ·20″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·15″ & ·20″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·15″ & ·20″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·15″ & ·20″.	Number of falls due to cyclonic storm.
Port Blair	...	...	...	...	...	...	1	...	1	1	2	1
Diamond Island	1	1	...	...	...	...	1	...	...	...	2	1
Akyab	1	1	...	...	...	...	1	1	...	...	2	2
Chittagong	...	...	1	1	...	...	...	...	...	...	1	1
Saugor Island	1	1	1	...	...	...	...	...	1	1	3	2
False Point	...	...	...	...	...	...	...	...	...	...	...	...
Gopalpur	...	...	...	...	...	...	...	...	...	...	...	...
Vizagapatam	...	...	...	...	...	...	...	...	...	...	...	...
Cocanada	...	...	...	...	...		1	1	...	...	1	1
Masulipatam	...	...	...	...	...	...	...	...	...	...	...	...
Madras	...	...	1	1	1	1	...	...	1	1	3	3
Negapatam	...	...	...	...	...	...	...	...	...	...	...	...
Trincomalee	...	...	...	...	...	...	...	...	...	...	...	...
Total for all Stations	3	3	3	2	1	1	4	2	3	3	14	11

Stations.	1883.		1884.		1885.		1886.		1887.		Total.	
	Number of times when barometer fell between ·20″ & ·25″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·20″ & ·25″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·20″ & ·25″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·20″ & ·25″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·20″ & ·25″.	Number of falls due to cyclonic storm.	Number of times when barometer fell between ·20″ & ·25″.	Number of falls due to cyclonic storm.
Port Blair	...	...	...	...	...	...	...	...	...	...	...	...
Diamond Island	...	...	...	...	...	...	...	...	...	...	...	...
Akyab	...	...	1	1	...	...	...	...	...	...	1	1
Chittagong	...	...	...	...	1	1	...	...	...	...	1	1
Saugor Island	1	1	...	...	...	...	1	1	...	...	2	2
False Point	...	...	...	...	...	...	...	...	...	...	...	...
Gopalpur	...	...	...	...	...	...	...	...	...	...	...	...
Vizagapatam	...	...	...	...	...	...	...	...	...	...	...	...
Cocanada	...	...	...	...	...	...	...	...	...	...	...	...
Masulipatam	...	...	...	...	...	...	...	...	...	...	...	...
Madras	...	...	...	...	...	...	3	3	...	...	3	3
Negapatam	...	...	...	...	...	...	...	...	...	...	...	...
Trincomalee	...	...	...	...	...	...	...	...	...	...	...	...
Total for all Stations	1	1	1	1	1	1	4	4	...	...	7	7

The first of the two preceding tables shows that the barometer fell during the period of five years upwards of ·15 inch at the selected stations on fourteen occasions, and that on at least eleven of these it accompanied and was caused by the approach of a cyclonic storm. The second table establishes that the barometer fell more than two tenths of an inch in 24 hours at the same stations on seven occasions, and that in every case it was due to an approaching cyclonic storm.

The preceding tables also show very clearly that falls of a tenth of an inch or upwards in 24 hours are of comparatively rare occurrence in the Bay. The number is much greater at Saugor Island and False Point than elsewhere. This is due to their position in the north-west angle of the Bay, nearest to the area in the north of the Bay where the great majority of the smaller storms of the rains proper (from June 15th to September 15th) are generated. Even at these stations falls of one tenth of an inch in 24 hours do not occur on the average on more than about eight to ten days in the eight months of the year from May to December. It is also almost certain that nowhere in the Bay are falls of a tenth of an inch or upwards in 24 hours more frequent than at Saugor Island, and probable that they are less frequent. Hence it may be fairly assumed as a general principle that they do not occur in any part of the Bay more than six or eight times in the year during the cyclone season. The third table shows that falls of two-tenths of an inch or upwards in 24 hours are of extremely rare occurrence, and in fact only happen when the inner storm area of a large cyclonic storm approaches or passes over the place of observation. Such falls are not likely to happen so often as once a year at single stations, and are hence of very rare occurrence.

It appears probable, *a priori*, that so far as the smaller fluctuations of the barometer from day to day in ordinary weather are concerned, they will probably be smaller in amount in the Bay than on land.

These figures hence abundantly illustrate an important feature in the meteorology of the tropics, *viz.* the smallness of the barometric changes from day to day. The steadiness of the barometer in the tropics, as compared with the temperate regions, is, it may be stated, mainly due to the slow rate at which the velocity of the rotation of the earth's surface alters in the tropics with increasing latitude.

(*E*) *The barometer in the Bay of Bengal rarely rises a tenth of an inch in 24 hours unless a cyclonic storm is either filling up near the place of observation or has been advancing away from it.* It is not so necessary to give data for this statement, as the principle is of much less importance than the preceding. The data, however, will help to establish the general principle of the smallness of the daily barometer changes in the Indian seas, and hence further confirm the data in the preceding paragraph. They also show that rapid rises of the barometer are more frequent in the Bay than rapid falls. This is, of course, only one phase of the general principle that the barometer rises more quickly after the passage of a cyclonic storm than it falls during its approach, or that the barometer rises more quickly in the rear of a storm than it falls in front. The following tables give data which establish the truth of this principle :—

A = Number of times when barometer rose between ·10" & ·15" (1884: ·10" & ·18"; Total: 10" & ·15.)
B = Number of rises due to passage of cyclone.

Stations.	1883. A	1883. B	1884. A	1884. B	1885. A	1885. B	1886. A	1886. B	1887. A	1887. B	Total. A	Total. B
Port Blair	...	...	...	...	...	...	1	...	1	1	2	1
Diamond Island	1	1	...	...	3	2	3	1	1	1	8	5
Akyab	2	2	3	3	5	3	4	1	7	5	21	14
Chittagong	3	2	2	2	4	3	3	1	2	1	14	9
Saugor Island	4	3	8	4	6	5	8	1	5	4	31	17
False Point	5	4	2	...	4	3	3	...	3	2	17	9
Gopalpur	1	...	2	...	5	4	3	2	3	3	14	9
Vizagapatam	3	1	3	3	4	2	3	2	4	3	17	11
Cocanada	2	1	1	...	2	1	2	1	2	1	9	4
Masulipatam	3	2	1	...	1	1	1	1	1	1	7	5
Madras	1	...	1	...	1	1	1	1	2	2	6	4
Negapatam	...	...	1	1	...	...	2	2	...	...	3	3
Trincomalee	1	...	...	...	...	...	1	1	...	...	2	1
Total for all Stations	26	16	24	13	35	25	35	14	31	24	151	92

A = Number of times when barometer rose between ·15" & ·20".
B = Number of rises due to passage of cyclone.

Stations.	1883. A	1883. B	1884. A	1884. B	1885. A	1885. B	1886. A	1886. B	1887. A	1887. B	Total. A	Total. B
Port Blair	...	...	...	...	...	...	...	...	...	...	...	...
Diamond Island	1	1	...	...	...	...	...	...	...	...	1	1
Akyab	...	...	...	...	2	1	...	...	1	1	3	2
Chittagong	2	2	1	1	1	...	...	...	1	1	5	4
Saugor Island	...	...	...	...	1	1	...	...	1	...	2	1
False Point	1	1	1	...	...	...	1	1	...	...	3	2
Gopalpur	1	1	1	...	...	...	...	...	...	...	2	1
Vizagapatam	1	1	1	...	...	...	1	1	...	...	3	2
Cocanada	...	...	...	...	...	...	1	1	...	...	1	1
Masulipatam	...	...	...	...	...	...	1	1	...	...	1	1
Madras	...	...	...	...	...	...	...	...	...	...	...	...
Negapatam	...	...	...	...	...	...	...	...	...	...	...	...
Trincomalee	...	...	...	...	1	1	...	...	...	...	1	1
Total for all Stations	6	6	4	1	5	3	4	4	3	2	22	16

STATIONS.	1883.		1884.		1885.		1886.		1887.		TOTAL.	
	Number of times when barometer rose between ·20″ & ·25″.	Number of rises due to passage of cyclone.	Number of times when barometer rose between ·20″ & ·25″.	Number of rises due to passage of cyclone.	Number of times when barometer rose between ·20″ & ·25″.	Number of rises due to passage of cyclone.	Number of times when barometer rose between ·20″ & ·25″.	Number of rises due to passage of cyclone.	Number of times when barometer rose between ·20″ & ·25″.	Number of rises due to passage of cyclone.	Number of times when barometer rose between ·20″ & ·25″.	Number of rises due to passage of cyclone.
Port Blair	...	...	...	...	...	...	...	...	...	...	...	...
Diamond Island	...	...	...	...	...	...	...	...	...	...	...	...
Akyab	1	1	...	...	...	...	...	...	1	1	2	2
Chittagong	1	...	...	...	1	1	...	...	1	1	3	2
Saugor Island	1	1	...	...	...	...	1	1	2	2	4	4
False Point	...	...	...	...	...	...	...	...	1	...	1	...
Gopalpur	...	...	...	...	...	...	...	...	1	...	1	...
Vizagapatam	...	...	...	...	...	...	...	...	1	1	1	1
Cocanada	...	...	...	...	...	...	...	...	...	...	...	...
Masulipatam	...	...	...	...	...	...	...	...	...	...	...	...
Madras	...	...	...	...	...	...	2	2	...	...	2	2
Negapatam	...	...	...	...	...	...	...	...	...	...	...	...
Trincomalee	...	...	...	...	...	...	...	...	...	...	...	...
TOTAL FOR ALL STATIONS	3	2	...	...	1	1	3	3	7	5	14	11

(*F*) The preceding principles (more especially *C* and *D*) hence establish the following important rule :—

> *If the barometer in the Bay of Bengal during the cyclonic season lasting from May to December falls more than ·15″ in the north of the Bay—or more than ·1″ in the centre or south of the Bay in 24 hours,—that is, if the difference between the reading of the barometer at the same place and at the same hour on two consecutive days differs by amounts exceeding ·1″ in the centre and south of the Bay or ·15″ in the north of the Bay,—it may be accepted as an almost certain indication that a cyclonic storm is forming in the neighbourhood, or that a cyclonic storm of considerable or great intensity is approaching it.*

The tables afford a measure of the probability that a fall of the barometer through the amounts stated is due to a cyclonic storm. It is also almost certain that this estimate of the probability will be below its real value for the reason already suggested, *viz.* that the smaller changes are more frequent and larger in the India land area than on the adjacent seas. For example, the data for the coast stations show that during the cyclone season a fall of a tenth of an inch in 24 hours immediately preceded or accompanied the formation or passage of a cyclonic storm in its neighbourhood in two cases out of three. Hence the chance or odds that a fall of one tenth of an inch is due to an approaching cyclone is two to one. Similarly, a fall of over ·15″ in 24 hours accompanied cyclonic storms in five cases out of six, or the odds that such a

fall, when observed in any future year, will be, so far as these data are concerned, due to a cyclonic storm, would be five to one. A fall of two-tenths of an inch in 24 hours was in every case due to a cyclonic storm, and hence may be accepted as practically a certain indication.

(G) An equally valuable and important principle is the following:—

It is very rare for the barometer to fall in the north of the Bay of Bengal more than two tenths of an inch (·20) below its normal height or more than ·15" in the centre of the Bay, and if it does so on board a ship at any place in the north or centre of the Bay, it indicates that pressure is below the normal or ordinary pressure by that amount at least, and is an almost certain indication that a cyclonic storm has formed, or is forming, in the Bay, the position of which can be ascertained from other indications.

It is not so easy to give data in proof of this statement, as the published records of the Department have not hitherto given the variation of the barometric readings at the coast stations for each day, except in the case of the Bengal station.

The following table gives data (for May to December) for the four years 1884-87, and shows how often in those years this indication was fulfilled for the three ports or coast stations selected, and for which data are available:—

Stations.	1884.		1885.		1886.		1887.		Total.	
	Number of occasions on which barometer fell over ·2 inch.	Number of occasions on which fall was due to storm.	Number of occasions on which barometer fell over ·2 inch.	Number of occasions on which fall was due to storm.	Number of occasions on which barometer fell over ·2 inch.	Number of occasions on which fall was due to storm.	Number of occasions on which barometer fell over ·2 inch.	Number of occasions on which fall was due to storm.	Number of occasions on which barometer fell over ·2 inch.	Number of occasions on which fall was due to storm.
Chittagong . .	1	1	...	...	...	...	1	1	2	2
Saugor Island . .	1	1	...	...	...	...	2	2	3	3
False Point . .	1	1	...	...	3	3	1	1	5	5

Stations.	1884.		1885.		1886.		1887.		Total.	
	Number of occasions on which barometer fell over ·25 inch.	Number of occasions on which fall was due to storm.	Number of occasions on which barometer fell over ·25 inch.	Number of occasions on which fall was due to storm.	Number of occasions on which barometer fell over ·25 inch.	Number of occasions on which fall was due to storm.	Number of occasions on which barometer fell over ·25 inch.	Number of occasions on which fall was due to storm.	Number of occasions on which barometer fell over ·25 inch.	Number of occasions on which fall was due to storm.
Chittagong . .	...	...	...	...	...	...	...	...	...	...
Saugor Island . .	...	...	...	...	1	1	1	1	2	2
False Point . .	1	1	...	...	1	1	...	...	2	2

Stations.	1884.		1885.		1886.		1887.		Total.	
	Number of occasions on which barometer fell over ·3 inch.	Number of occasions on which fall was due to storm.	Number of occasions on which barometer fell over ·3 inch.	Number of occasions on which fall was due to storm.	Number of occasions on which barometer fell over ·3 inch.	Number of occasions on which fall was due to storm.	Number of occasions in which barometer fell over ·3 inch.	Number of occasions on which fall was due to storm.	Number of occasions in which barometer fell over ·3 inch.	Number of occasions on which fall was due to storm.
Chittagong . .	...	...	...	...	...	...	...	...	...	...
Saugor Island . .	...	...	...	...	1	1	1	1	2	2
False Point . .	...	...	...	...	...	...	...	...	...	...

The practical bearing of the preceding rules or principles, more especially in connection with the prevision of cyclonic storms, is almost self-evident. This feature of the subject is dealt with in the next chapter.

Temperature.—Temperature is that property or state of a substance in virtue of which it can take in or give out heat, and thus become hotter or colder.

In the case of air, it is almost always measured by means of the thermometer. The instrument is too well known to need description. It is moreover one of the easiest of meteorological instruments to read and observe. It is, for almost self-evident reasons, of little or no value or use in forecasting bad weather or storms in the Bay of Bengal. It is hence unnecessary to give instructions for the best manner of exposing thermometers at sea, or to state the precautions that ought to be taken to secure the most accurate observations of temperature by its employment.

There are, however, one or two points of interest in connection with the temperature of the air in the Bay of Bengal that deserve statement.

The air, as is of course generally known, is transparent to the sun's heat far more perfectly than glass is to light. In other words, the air offers little obstruction to the passage of the sun's heat through it, and permits it to reach the earth's surface only slightly diminished in amount. The heat or light which disappears in the passage of the solar rays through the atmosphere, and is taken up by the air, is said to be absorbed, and the process is called absorption. The sun's heat, or solar radiation as it is scientifically termed, in passing through the air produces hardly any effect on it, or does not increase its temperature. It should be carefully borne in mind by all who study the changes of weather and their causes, that in clear weather the sun does not heat the air around us directly.

When, however, the sun's heat meets with a body which obstructs it and does not permit it to pass on, nor throws it off by regular reflection, as in the case of a bright piece of metal, the body becomes rapidly heated at and near the surface. Hence the action of the sun during the day is to heat the earth's surface. If this be land, and especially if it be dry land, as in the interior of India in the hot-weather months of March, April, and May, its temperature increases rapidly from sunrise until shortly after mid-day. The temperature of the earth's surface at Allahabad, for example, in the month of April, increases on the average from 65° at 6 A.M. to 136° at 2 P.M., and at Jeypore from 65° at 4 A.M. to 124° at

4 P.M., and in the sandy tracts of Rajputana, &c., it probably increases even more, and perhaps as much as 80° from sunrise to mid-day. This heated surface plays the same part with respect to the air that a fire does with respect to the water in a kettle placed above it. The air at and near the earth's surface becomes heated by contact with it and by the process known as convection.

Hence in the hot weather in India the earth's surface over nearly the whole of the interior of the country is heated by amounts varying with the nature of the soil from 40° to 70° or perhaps even to 80° during the morning and mid-day, and cools again by the same amount during the evening and night. This heats the air near the earth's surface very rapidly during the day, but by a smaller amount. For instance, at Allahabad the air is heated 32° on the average from sunrise to midday in the month of April, that is, practically in the same time that the surface soil is heated 71°, and at Jeypore it is heated 26° in the same time that the ground surface is heated 59°.

Hence it is that in the months of April and May, when the ground is driest, the skies generally free from cloud, and the sun almost vertical over Central and Northern India, the mean daily temperature increases very quickly from week to week, and also the actual temperature during the day rises very rapidly from sunrise up to 1 P.M. or 2 P.M., when temperatures varying from 110° to 120° are common over the greater part of the interior of India. The result of this rapid increase of temperature during the morning is that the air is 25° to 35° or 40° hotter in Upper and Central India than it is at the same hour of the day in the open seas to the south-east and west of India.

The conditions are quite different when the sun's heat and rays fall upon a large water surface such as the Bay of Bengal. In that case it is almost entirely utilized in evaporating water from the surface, and hence produces hardly any change in the temperature of the water. Observations of the temperature of the sea water in the deeper portion of the Bay (not in the shallows near the Bengal and Orissa coasts) show that it varies less than 2° or 3° during the day. Hence also the air overlying the water surface, the heating of which depends mainly upon the temperature of the surface it rests upon, will maintain a nearly steady temperature, not only throughout the day, but from day to day.

Hence, when it is remembered that in the Bay of Bengal the winds that prevail during the whole of the year, except in the months of December and January, and sometimes February, are sea-winds, *i.e.* winds that advance over the surface of the sea for long distances, it will be at once evident that the temperature of the air in the Bay of Bengal will be remarkably uniform during the greater part of the year, *i.e.* March to November. There are in the Bay of Bengal no cold land-winds or polar winds which bring down masses of cold air and thus reduce the temperature, such as often occur, for example, in the North Atlantic.

Hence one of the most remarkable features of the Bay of Bengal during the whole cyclone period, April to December, is the very great uniformity of temperature. It will be sufficient to give a few facts in support of the preceding statements. During the three months March to May the mean temperature of the Bay in the open varies from 84° to 86°. From June to August it varies from 81° to 83°, so that the constant cloudy weather of this period only reduces the mean temperature 3°. From September to November it varies from 80° to

83°. And as the daily range does not exceed 3°, it will be evident that during this period of nine months the temperature is rarely less than 78° and hardly ever exceeds 88°, or that the total range of temperature is about 10°.

The following table gives the mean *day and night* temperatures that may be expected in each month of the year in the Bay of Bengal and the Arabian Sea away from the land, and where the temperature is that of the sea proper, uninfluenced to any large extent by the land. It also gives the daily range of temperature and the mean highest day and lowest night temperatures in the hottest part of India in each month for comparison :—

	Sea area.			Land area, hottest part of India.		
	Mean Maximum.	Mean Minimum.	Mean range.	Mean Maximum.	Mean Minimum.	Mean range.
January	82·2	79·4	2·8	88·9	69·5	19·4
February . . .	83·3	80·0	3·3	97·4	72·3	25·1
March . . .	84·2	80·6	3·6	103·8	72·4	31·4
April	85·5	81·7	3·8	108·0	73·0	30·0
May	84·1	82·3	1·8	109·7	80·8	28·9
June	83·4	81·4	2·0	107·1	82·8	24·3
July	82·8	80·7	2·1	107·7	84·3	23·4
August . . .	83·8	81·1	2·7	103·4	81·7	21·7
September . . .	82·4	80·2	2·2	99·3	80·7	18·6
October . . .	82·7	79·8	2·9	100·1	66·2	33·9
November . . .	81·8	79·6	2·2	86·3	62·0	24·3
December . . .	82·6	79·6	3·0	88·6	64·0	24·6

Evaporation.—If a vessel of water be exposed, the water gradually disappears, rapidly in hot dry weather, and most rapidly if exposed to the sun in such weather, and slowly, if exposed in the shade when the air is cool or damp. The name of the process by which the visible liquid water is converted into the invisible gas called aqueous vapour is called *evaporation*. The converse process by which the aqueous vapour is reconverted into water is termed *condensation*. Aqueous vapour, it should be carefully remembered, is an invisible gas, and its presence in air can only be ascertained indirectly, and it is only when it begins to condense into small drops, or globules, of water that the aqueous vapour present in the air becomes visible.

Condensation.—There are various methods by which the conversion of the aqueous vapour from the state of gas into that of water may be effected. The process itself is called condensation. If, for example, the invisible steam in a boiler be allowed to rush out into the comparatively cool air, it condenses into excessively small globules, which become visible, and which have the same relation to a mass of water that the particles of a piece of glass which has been ground into fine powder bear to the original glass. If the powdered glass, consisting of an immense number of unconnected particles, be looked at, it appears to be white, whilst the glass before being powdered was transparent as water. A large number of very minute particles, or globules, of water in a cloud, for similar reasons, appear white when light falls upon them. Such masses, or large collections, of small globules of water form clouds, fogs, or mist.

The colour of clouds depends mainly upon whether light is falling upon them from the sun or passing through them and to what extent. If the minute globules from any cause, either by further condensation on their surfaces, or by uniting together, increase in size, they then fall down more or less quickly (depending on the size of the drops) and give rain. It has recently been shown that electricity or electric action tends to cause small globules of water to unite together rapidly and form larger ones. This is probably the chief cause of the large size of rainfall drops in thunder storms.

Actions accompanying condensation and rainfall.—Much might be said about the actions accompanying condensation and evaporation. It will be sufficient to consider the following examples. A mass of air containing invisible aqueous vapour rising up from the warmer valley of a hill district to the cooler hill sides and summits, may, it is well known, be cooled down sufficiently to cause the aqueous vapour to be converted into the visible form of minute drops, and produce a cloud or fog at and near the summit of the hill. When the air, carrying along with it this visible cloud, advances beyond the hill top and sinks down, the small drops are re-evaporated and pass again into the invisible state. A cloud formed in this way at and near the summit of a hill may be more or less permanent in appearance for hours or even for days. It is nevertheless in a state of constant change. Similarly, in a cyclonic area where the air is drawn in from all quarters and rises from the lower warmer strata of the atmosphere to a higher and cooler level, the aqueous vapour is condensed and forms clouds. In this case, too, the clouds are more or less permanent in appearance, whilst the aqueous vapour in passing through the cloud space is condensed, and collected into larger globules which fall as the torrential rain that invariably accompanies cyclonic storms in the tropics. Hence it is that the cloud bank, indicating the existence of a near and perhaps approaching cyclone, appears for hours almost unchanged in shape and magnitude, whilst all the time it is the seat of the most rapid and violent actions and changes.

There is one point in connection with the aqueous vapour of the atmosphere that is of very great importance. Before taking it up it is desirable to refer again as clearly as possible to one or two of the more elementary conceptions of modern science respecting work and energy.

Conversion of energy.—In order that work may be done, it is not only necessary that force should be applied, but that it should act through a distance. For example, a coolie may exert force to support a heavy box, but he does no work unless he removes the box from one place to another—that is, exerts force on the box through the distance between the first and second place. A blacksmith will do no work, if he merely keeps a hammer suspended above a mass of iron. He must lift it up, and allow it to fall, and the more rapidly he does it (with judgment) the greater the amount of work he will do in a given time, and so on for other cases. Again, force may be exerted and work may be done either directly by man, or indirectly by utilizing with suitable machinery the forces available in nature. It may be the wind used to drive a mill or to carry a ship over the ocean, or running or falling water employed to drive water-wheels, turbines, &c., or the sun and moon in producing tides, &c. But in all these arrangements, whatever does work loses something in virtue of which it was able to

do work, and if this something is limited in amount it can only do a limited amount of work. This *something* is called energy. Thus every pound of coal before it is burnt contains a definite amount of energy, and, by means of a steam engine, can be made to do work. But when the energy has been taken out of it,—that is, the coal has been burnt and utilized to heat the water in the boiler, and convert it into steam in order to pass it through the cylinder and drive the machinery,—it is exhausted and is of no further use, and is therefore usually thrown away as refuse. This change, or loss of energy, or of power of doing work, or producing change, is continually going on in nature around us, as well as in our manufacturing towns, steam-vessels, &c. For example, the sun is constantly giving out heat (exactly like the furnace of a steamer), and is therefore yielding up or losing energy. This heat or energy thus given up produces various effects and does work of various kinds. One very important effect or kind of work performed by the sun is that of evaporation. The sun heats the surface-water of the ocean and converts it into the invisible form of aqueous vapour which passes upwards unperceived through the atmosphere until it reaches a level where it is cooled down and condenses again into the water globules of a cloud, &c. But every pound of water thus evaporated represents a certain definite amount of work done upon it by the sun which is now known very approximately, and can be calculated as easily and exactly as the horse power of the engines of a steamer, or the actual work done by an engine in a definite number of strokes, or in a given time. Also work done on a body, as in the case of a hammer or a cannon ball, gives it energy, or the power of doing work, which may again be utilized in doing work. Hence the very important principle that work and energy may, and should, be measured by the same measure, in the same way as the power of being able to pay for articles usually represented by a balance at a banker's, and the actual payments received by persons for value given should be measured in the same manner, *e.g.* pounds sterling in England, or rupees in India.

A second important principle is that work done upon any mass of matter always produces some change, and in many cases the change thus made can be undone; and when this is the case, the body, in returning to its original state, can do an amount of work less than or equal to, but never greater than, the amount spent upon it to produce the change of state. Such changes are examples of what are called conversions or transformations of energy.

Illustrations of conversion of energy.—Thus, for example, a person does a certain amount of work in winding up the spring of his watch, and the spring, in gradually unwinding itself, does an amount of work in moving the very light and delicate wheels and pointers of his watch, which is (in consequence of friction) slightly less than the work done by the man in winding it up.

Similarly, a number of labourers engaged in pile-driving may lift up slowly a heavy mass of iron (the pile hammer) some distance and then let it drop down. The workmen, whilst lifting the pile hammer, do work in changing its position, and the pile hammer in returning to its original position gives out energy to the pile, or does work upon it, which, as before is slightly less than the work done on the iron mass by the workmen whilst lifting it. Any one thinking over the matter for himself can suggest numbers of illustrations, but

the two we have given are sufficient to suggest a very important principle in connection with these changes. In the case of the watch the action of the man in winding it up is comparatively vigorous and lasts only for a few seconds. This action or energy is given up by the watch continuously for a space of, say, 24 hours, and hence the intensity of action of the watch is excessively feeble. It is an example of the conversion of a very brief but vigorous action into a prolonged feeble action.

The second illustration is an example of the opposite change. The process of lifting the pile driver or hammer is slow and laborious. A moderately strong force is exerted for a considerable interval of time by a number of workmen. The pile hammer, after falling down, acts on the head of the pile for an extremely short interval, at the instant of contact, probably for not more than a fraction of a second, and hence the intensity of the action is very great.

An important principle of conversion of energy, *viz.* that the intensity of action varies inversely with the time of action.—Both the cases used for illustration in the preceding paragraph are analogous to the principle of the lever—with which every one is familiar. In the case of that instrument, a feeble force, acting through a considerable distance, may exert or give rise at the other extremity of the lever to a large force acting through a small distance, but whatever increase of force is gained by its use, the distance through which it acts is proportionately diminished, or, as it is usually expressed, what is gained in force is lost in distance. In considering the changes or actions we are now contemplating, we have to remember that there are, as in the case of the lever, two elements. These are, in the present case, intensity of action and the duration of the action. It is almost self-evident that in the case of any transfer of energy or performance of work by machinery, whatever we can gain in one of these elements is lost in the other. These will hence illustrate the principle that in any conversion of energy what is gained in intensity is lost in time, or that the duration of the action diminishes at the same rate as the intensity increases.

Hence it is that the energy of the electrical discharge of a thunder-storm is very small indeed. It can produce very violent effects depending upon mere intensity of action, but the duration of action of a flash of lightning is so excessively small that the amount of work it can do is small, and it has been shown most conclusively, by distinguished men like Faraday and Tyndall, that a pound of coal contains more energy and can do more work than the whole of the electricity generated during a thunderstorm.

Application of the preceding principles to the processes of evaporation and condensation.—These remarks, it will be seen, have a most important bearing on our subject.

The sun in evaporating water does a certain definite amount of work on each pound of water in changing its state into aqueous vapour. When the aqueous vapour is reconverted by any method into water and returns to the earth's surface, it yields up the energy given to it by the sun, in virtue of which it can do an amount of work practically equal to that done by the sun in evaporating it.

The most important question, then, in connection with this reconversion of the aqueous vapour into water is the rate at which it takes place—that is,

whether the action is like that of the watch or the pile hammer after it has been acted on by man. The following reasons will show that it resembles that of the pile hammer rather than that of the watch.

It is believed, from a large number of experiments that have been made (as for example measuring the depth of water evaporated in tanks in India, &c.), that the amount of heat energy which comes from the sun and falls on every square foot of surface of the Bay of Bengal is sufficient to do the work of evaporating a tenth of an inch of water in one day, or nearly eight ounces of water. According to some the amount may be as much as one-fourth of an inch or upwards of a pound of water per square foot of surface, or about seventy-five million tons of water per square degree of surface of the Bay of Bengal. We shall assume for the purposes of the argument that the evaporating power of the sun per square foot of surface is one-quarter of an inch, and this may hence be taken as a measure of the sun's activity at and near the earth's surface.

The sun's action or energy, it may be remarked, passes through the earth's atmosphere without doing any large amount of work upon it directly. If the opposite were the case, the upper portion of the atmosphere would be hotter than the lower, which it is well known is not the case. The sun's heat and light action is hence on clear days transmitted almost undiminished in amount through the atmosphere, and it is only when it acts upon the surface of the earth that it produces change or does work. When it falls upon a dry land surface it heats it rapidly, and the heated surface then imparts a portion of its heat to the air by the same kind of process and motion as that which takes place when water is boiled in a kettle over a fire. It is by this kind of heating mainly that the air becomes hotter during sunny days, and not by the direct action of the sun. On the other hand, when the sun's heat falls upon the surface of water, or very damp soil, its action is almost entirely confined to evaporating the surface water. Hence the effects of sun's heat at land and sea are essentially different. In the latter case, it is continuously during the day adding to the amount of aqueous vapour in the air, but produces hardly any change of temperature, &c., in the air itself. In the former case, or in the interior of a country like India, the sun's action during the day produces indirectly very considerable changes of pressure, density and temperature, and as the air is not contained in a closed space and is free to move, these changes are accompanied by a very considerable amount of motion, in part ascensional and in part horizontal. Hence it is over the land that many of the changes take place which initiate winds and changes of winds. For example, land and sea breezes are due to the rapid heating of the land in the day time as compared with the sea, and its equally rapid cooling at night.

And it is evident that if there were no action due to the varying amount of aqueous vapour in the air or to the processes of evaporation and condensation, the chief cause of the motion of the air or of winds would have to be sought for solely in the different heating effects in different latitudes or on land and at sea. Such actions are sufficient to explain satisfactorily the trade winds, land and sea breezes, the hot day winds of Upper India in April and May, &c. But these are all comparatively feeble winds, and not in any way comparable in force to the violent hurricane winds of cyclonic storms in the Bay of Bengal, and it is

therefore evident that these strong storm winds must be due to some other action than the heating of air by contact with surfaces of land exposed to the powerful rays of a tropical sun.

There is only one known action which appears to be adequate to explain these winds. In all the larger and more violent cyclonic storms of the Bay of Bengal there is always heavy, and almost continuous concentrated rain over the inner storm area, and frequent rain squalls in the outer storm circle, whilst beyond the area of disturbance the weather is fine and clear for very considerable distances to the north, east and west. The character of the rainfall in the storm area itself is described in the vigorous language of sailors as "torrential," "heavy blinding rain," "rain in a solid mass," "a deluge of rain," &c. Judging from the rainfall that occurs during the passage of cyclonic storms across India, it is almost certain that near the centre rain falls at the rate of 1½ to 2 inches or even more per hour. The amount of rain at any place not only depends upon its intensity, but upon its duration, which in cyclonic storms depends upon the magnitude of the storm and the rate of its motion. Rainfalls of from 5 to 10 inches at places passed over by cyclonic storms are quite common in India after they reach land. Rainfalls of from 10 to 20 inches are of comparatively frequent occurrence, and of from 20 to 30 inches of occasional occurrence. Hence it is quite within the mark to assume, as a fair average estimate, that 10 inches of rain fall over the inner storm area of a large and intense cyclone during every 24 hours of its existence as a violent storm.

Taking the estimate of the sun's power per day to be equivalent to that required for the evaporation of a depth of one-quarter of an inch of water, it is evident that over the storm area forty times as much water would be condensed and poured down as rain, as the sun is able to evaporate in the same interval, that is, in this case the work of condensation would go on forty times as rapidly as that of evaporation goes on in the Bay in fine sunny weather. Hence also, forty times as much energy would be given out by the condensed aqueous vapour to the surrounding air as could be given by the direct action of the sun. In other words, there is in such a storm an action going on, and a conversion of energy which is very much more intense and powerful than the direct action of the sun, and can therefore produce much more rapid and greater changes and motions. If the rainfall be heavier than 10 inches per 24 hours, the action will be proportionately more intense.

The energy given up during condensation appears to be communicated to the air directly and produces rapid increase of its motion. The aqueous vapour in this case may hence be compared to the coal which is necessary to heat the boiler of a steam-engine or steam-vessel. Each of them, *i. e.* coal and aqueous vapour, contain a certain amount of energy per pound of mass. In the one case the coal gives up its energy, by the process of burning or combustion to the water or steam in the boiler, in virtue of which it is able to move the mechanism of the vessel. In the second case the aqueous vapour gives up a portion of its energy whilst being converted into water by the process of condensation, and communicates that energy to the air which is hence put into violent motion.

There are several important features in this transfer of energy which should be remembered:—

First.—It is a direct action or effect upon the air and not an indirect one, and is hence different from the heating of the air during the day which is due indirectly to the sun heating the earth's surface. Practically the whole of it is hence utilized in producing changes in the motion of the air.

Second.—It is continuous and not intermittent like the sun's action on the earth or the surface of water and is not suspended at night.

Third.—It is, in the case of heavy cyclonic rainfall, a very much more intense action than the direct action of the sun. If we call the ordinary action of the sun a sun-power, this action might be twenty, fifty or even one hundred sun-power.

Fourth.—It is given out to a very limited mass of air compared with that acted upon directly by the sun. The sun's action, for example, extends almost equally over the whole of India and the Bay, and its power differs comparatively little at different places during the hot weather and rains. The action of rainfall on the contrary is local and hence produces a very large effect on a limited mass of air (or a very large local disturbance which is the primary feature of cyclonic storms), and very little at a distance of 200 or 300 miles. It hence gives rise to very great differences of condition at moderate distances, and this, it is hardly necessary to point out, is the most essential feature of a large local disturbance.

In order to ascertain the chief motive power of cyclonic storms or the energy given out during the process of condensation of aqueous vapour and of rainfall, it would be necessary for a complete enquiry to ascertain the conditions under which this action of rainfall takes place and more especially the conditions necessary for the peculiarly concentrated and localized heavy rainfall that accompanies and maintains cyclonic storms. This however is not necessary in the present little work, as the chief object of these remarks has been to direct the attention of the sailor to the real motive power, and hence by inference to suggest that electricity, or the moon, are utterly inefficient, and not to give a full account of the various theories that have been suggested at different times to explain the origin and phenomena of cyclones.

In the preceding paragraphs a very brief explanation has been given of what may be termed the motive power of cyclones. It is not, of course, a complete explanation of all the actions accompanying cyclones. To return to our illustration: it is not merely sufficient to have coal in order to produce rapid motion of a ship, but it is absolutely necessary to have a complicated apparatus and men to guide and control that apparatus or machinery. The machine or steam-engine is as necessary for the conversion of the energy of the coal into the motion of the ship as the coal itself. Similarly, in the case of cyclones, whilst the motive power is derived from the condensation of aqueous vapour, various conditions have to be fulfilled in order that this motive power may originate and maintain a cyclonic storm.

Humidity.—The process of condensation and of rainfall is of much importance in meteorology from another point of view. Aqueous vapour passes into

the air by evaporation and mixes with it. A very important property of air is that a given space, say a cubic foot, will only contain a definite quantity of aqueous vapour and no more, the quantity depending on the temperature, the higher the temperature the larger the quantity and *vice versâ.* When a given quantity of air contains the largest possible amount of vapour that it will contain at a given temperature, it is said to be *saturated.* In fact air in this respect may be compared to a sponge, which will only absorb a definite quantity of water (it may take less but not more), or a vessel of warm water which will dissolve a certain amount of salt. The air is usually not saturated, but contains a smaller amount of the invisible gas called aqueous vapour than is possible. The ratio of the actual amount it contains to the largest possible amount it could contain at that temperature is called the *humidity*, and is usually expressed as a percentage. Thus, if it contained half the largest possible amount, the humidity of that portion of air would be 50 per cent., and if three-quarters of the total possible amount without condensation, the humidity would be 75 per cent. (because 75 is ¾ths of 100). A knowledge of the humidity or amount of moisture in the air is of great importance in land meteorology. It is of very little value or interest indeed in the Bay of Bengal, because the humidity of the air near the surface of the water is always high and the air not far from saturation. The methods of obtaining the humidity are more or less complex, and as its knowledge is practically of no use to sailors in forecasting storms or ascertaining their position with respect to a storm already formed, it is unnecessary to give these rules, or to recommend sailors in the Bay of Bengal to observe the wet and dry bulb thermometers for their own information, although of course accurate observations taken at sea may be of great use to meteorologists for scientific investigation.

Processes of condensation of aqueous vapour in nature.—Since the air can contain less vapour in the invisible state at a lower than a higher temperature, if a given quantity of air be taken and be cooled down far enough, it will arrive at a state when it is saturated, and if it be cooled still further, it cannot contain that amount of vapour in the invisible state, and the surplus will be condensed into small globules of water forming a visible white mass. The process of condensation in nature on the large scale is hence always due to cooling the air below the temperature of saturation by some process. There are various ways in which this may occur, but it will be sufficient to mention two. The first is by the air near the earth's surface on dry calm cold nights being cooled down by contact with the earth's surface which cools rapidly by giving out the heat it has absorbed during the day. In this case if the cooling be sufficiently great, the air near the earth's surface will fall below the saturation point and condensation will take place, and mist, fog, &c., be formed. This method never gives rain, as it occurs through too small a depth of air for the formation of large drops and therefore for rainfall. The second, and by far the most general cause, is due to the cooling of air that is rising higher and higher above the earth's surface. An ascending column of air is the most fruitful source of rain that occurs in nature. The reason of this is not difficult to understand. The given mass of air in rising up passes through air which presses less and less vigorously on it as it rises. In other words, the external

pressure on it diminishes. The air is then able to swell out, pushing aside the surrounding air to a large extent as it rises. But in pushing aside the outside air it exerts force through a distance or does work. As a body doing work necessarily loses some power of doing work or energy, the air in expanding during its ascent loses energy, and the energy which it loses is not chemical energy, electrical energy, &c., but heat energy. It in fact acts on the same general principle that lies at the root of the action of the steam-engine. If, then, a portion of it by rising and expanding cools down, and if this motion of ascension proceed high enough, the air will cool below its saturation point, and some of its invisible vapour will be converted into visible globules forming a cloud.

Rainfall.—It has been already pointed out that the enormous energy of cyclones in the Bay of Bengal is almost entirely derived from the change of the aqueous vapour present in the air into rain by the process of condensation. As the largest and most intense cyclones in the Bay of Bengal are far more severe and intense than storms in the temperate regions of the Atlantic Ocean, and have features which are either absent or are not conspicuous in those storms, as, for example, storm wave, calm centre, &c., this would naturally suggest that the rainfall in tropical cyclones is almost certainly much greater than ever occurs in the storms of the North Atlantic Ocean. This cannot be proved by actual measurement of rainfall at sea, as no satisfactory method has yet been generally introduced for measuring rain on board ships. The descriptions of cyclonic storms in tropical seas, as given in the logs of vessels, however, abound in expressions evidencing the extraordinary intensity of the rainfall. The following are quoted from logs which have been sent in during recent storms in the Bay of Bengal:—"Terrific rain," "Sheets of rain," "Torrents of rain," "Blinding rain," "Continuous heavy rain," "Steady hard rain," "Thick rain," "Incessant rain," "Thick blinding rain," "Deluge of rain," "Rain coming in a solid mass," &c.

As the storms which form in the Bay of Bengal all pass landwards into India, the rainfall which occurs during their march across Northern or Central India will give an estimate of the amount of rain which falls under favourable cyclonic conditions and during cyclonic storms in the tropics. The following are some of the more remarkable rainfalls in India during the past 10 years:—

Table showing the remarkable rainfalls at different parts of India, during the period 1878-88.

Year.	Month.	Date.	District.	Station.	Amount of fall exceeding 20 inches measured in 24 hours.	Remarks.
					Inches	
1878	June	19	Khasi and Jaintia Hills	Jowai	20·60	
	Aug.	26		Do.	23·40	
	"	...		Cherra Poonjee	24·60	
	"	27		Jowai	26 70	
	Oct.	31	Kolhapur	Shirol	20·00	
1879	June	4	Khasi and Jaintia Hills	Jowai	22·70	
	Sep.	13	Purneah	Purneah	35·38	During a small cyclonic storm.

Year.	Month.	Date.	District.	Station.	Amount of fall exceeding 20 inches measured to 24 hours.	REMARKS.
					Inches.	
1880	Aug.	11	Khasi and Jaintia Hills	Cherra Poonjee	27·13	
	"	13		Jowai	22·96	
	Sep.	18	Bijnor	Nagina	32·40	During a cyclonic storm.
	"	...	Do.	Dhampur	30·40	
	"	...	Do.	Najibabad	28·50	
1882	June	3	Ratnagiri	Dapoli	21·08	Ditto.
	"	4	Do.	Chiplun	21·00	Ditto.
	"	16	.	Sutna	22·15	Ditto.
	"	18	Cawnpore	Derapur	20·00	Ditto.
	July	7	Bareilly	Nawabgunj	21·00	Ditto.
	Oct.	3	Patna	Gopalgunj	22·02	Ditto.
1885	June	14	Khasi and Jaintia Hills	Jowai	22·30	
	"	15		Do.	29·20	
	July	2		Do.	22·60	
	Sep.	9		Do.	24·36	
	"	8		Cherra Poonjee	22·11	
1886	June	18	Colaba	Roha	24·80	Ditto.
1887	"	1	Khasi and Jaintia Hills	Cherra Poonjee	22·90	
	"	25		Do.	25·04	
1888	May	27		Jawai	30·20	
	June	26		Do.	22·50	
	"	27		Mahadeo	25·80	

Cloud Observations.—The observation of clouds is very important. By means of observations of the forms of clouds and of the direction in which they are moving, it is often possible to obtain early indications of the approach of a cyclonic storm, or of bad weather, some hours before the barometer begins to fall.

Cloud observation requires much practice and intelligence, as it depends mainly upon the judgment of the observer, and not at all upon reading a measurement by means of an instrument. Sailors are usually good observers of clouds, and it is much to be wished that they would record their observations fully and send them in to Meteorological Offices, more especially in India, where the cloud observation is the least satisfactory part of the work of our observers.

Unfortunately there is yet much difference of opinion amongst Meteorologists as to the best methods of observing, naming, and describing clouds. In the following paragraphs are given, first of all, the names of clouds (with a brief description) at present employed in the India Meteorological Department, and also a brief statement of the latest proposals for cloud nomenclature suggested by the two chief European authorities at the present time on the subject of clouds and their relation to storms, &c., *viz.* Professor Hildebrandsson and the Hon. Ralph Abercrombie.

What a cloud is.—A cloud is an aggregate of very small particles of condensed water vapour, either in the liquid form of water or the solid form of ice. Hence a cloud may be regarded as a mass of "water dust" or "of ice or snow dust." If aqueous vapour is condensed in the lower strata of the atmosphere where the temperature is above 32° or the freezing point, it takes the form

of very small globules of water. If, on the other hand, it is condensed in the higher regions of the atmosphere where the temperature is below 32°, it is converted into tiny crystals of snow.

Object of cloud observation.—Cloud observations, as usually made, include estimates of their amount, form, and movement. The form and motion of clouds give us the only information we can obtain, without the use of balloons, of the changes in progress in any part of the atmosphere removed from the earth's surface and of the direction and rate of motion of the higher strata. Barometers, thermometers, wind-vanes, &c., tell us the conditions (such as, for example, pressure and temperature and direction of motion) of the air at the place of observation only, and hence at or very near the earth's surface.

The existence of a cloud at any elevation indicates that the atmosphere in the space occupied by the cloud is in a state of saturation, and that the vapour is being condensed. The shape of the cloud also tells us some of the conditions under which this air space became saturated and the cloud was formed, and hence indicates to some extent changes which are going on in the air above us and may affect the weather at the earth's surface. Finally, their direction shows what winds are blowing high up in the air. The observer is thus enabled by comparing the direction and rate of motion of the air at the earth's surface and at different heights in the atmosphere to ascertain whether weather is settled or unsettled, and what changes in the weather may be expected.

Cloud proportion.—The proportion of the sky covered by clouds is estimated by simple inspection. A sky wholly overcast is recorded as '10' and all minor degrees of cloudiness by the lower numbers from 9 downwards, the figure '0' being used to indicate an unclouded sky. From the nature of the observation an approximate estimate only is possible; but with a little practice it will be found easy to make it with sufficient accuracy for practical requirements.

Kinds of Clouds.—Clouds may be roughly divided in respect of their apparent shape and form into two great classes—first, the fibrous or linear, which tend to arrange themselves in lines or streaks, and the lumpy or massive, which tend to arrange themselves into piles or heaps. Each of these two forms is subdivided, partly according to their shape and partly according to their altitude.

The following gives the names of clouds as at present used by observers at meteorological observatories in India:—

1. Cirrus.	5. Pallio-cirrus.
2. Cirro-stratus.	6. Pallio-cumulus.
3. Cirro-cumulus.	7. Cumulus.
4. Pallium.	8. Fracto-cumulus.

The following gives a description of each of these so far as is possible in words:—

Cirrus is the most lofty of all clouds as it is seen far above the highest mountain peaks of the Himalayas and is probably never lower than six miles. It hence consists of minute snow crystals and forms feathery fringes or brushes, and is always more or less fibrous, or feathery, in appearance. The cloud tufts sometimes lie in very fine, delicate threads; at other times they are collected in

wisps, like tufts of white hair, when they are called by sailors "mare's tails," and at other times they are arranged as if forming sprays of small, white feathers. When this cloud is increasing in amount it forms frequently an interlacing net-work or sheet of filmy ice mist.

Cirro-stratus is also a lofty cloud, but lower, denser and more sheet-like than cirrus. It is, however, at such a height that it consists of snow crystals, but is sometimes of such thickness as to dim and obscure the sun's disc. It is this cloud which usually produces halos round the sun or moon. Its form is very variable. It sometimes appears as an almost uniform sheet; at other times it is broken and very frequently assumes a wavy or undulatory appearance, especially near the horizon. When it does not extend over the whole sky it thins off towards the edges, and when seen in the morning or evening low down near the horizon, it presents the appearance of horizontal streaks and is then frequently misnamed stratus.

Cirro-cumulus is also a lofty cloud which forms on the breaking up of the fifth kind of cloud, *viz.* pallio-cirrus. It frequently consists of an immense number of little rounded cloud tufts, or masses of cloud, more or less regularly arranged, and is then known as "mackerel sky."

Pallium.—When the cloud masses increase and combine into a thick watery-looking mass covering the sky, threatening rain, the whole is called *pallium*. It formerly was known as nimbus. The whole cloud mass pallium usually consists of two portions, *viz.* Pallio-cumulus and Pallio-cirrus.

Pallio-cumulus usually forms the thick mantle constituting the lower layer of pallium, or rain cloud. It is formed by the rapid increase and joining together of masses of cumulus, and generally extends to greater heights than the ordinary cumulus of fine weather.

Pallio-cirrus.—Is the upper layer of the pallium, or rain cloud, and is sometimes separated from it by a cloudless interval. It is a thick and lofty sheet of cloud which obscures the sky, and is usually formed by the descent and thickening of cirro-stratus cloud.

Cumulus.—This is by far the most common form of cloud in the tropics. Cumulus clouds usually form isolated masses of clouds, with rounded summits and flat bases, all at about the same level, and, when seen near the horizon, the towering masses have frequently the appearance of a group or range of high hills. They very frequently form in fine weather in the tropics. They begin to show themselves some time after sunrise, increase until the afternoon, and then gradually disappear again before evening. The masses of cumulus cloud which form in the day mark the summits of ascending columns of air which reach saturation at the level marked by their bases and above that level deposit their excess of moisture as cloud.

Fracto-cumulus.—Is the name given to the broken irregular masses into which pallio-cumulus is resolved when in the act of breaking up or is torn by the wind. Like cumulus, it is essentially a cloud of the lower atmosphere. The term "scud" is commonly applied to all such loosely-formed clouds when drifting very rapidly before the wind.

Hildebrandsson's classification of clouds.—According to the opinions of Abercrombie and Hildebrandsson the forms of clouds are very numerous and it

requires special training and very careful observation to discriminate between the finer varieties. This close and exact observation is however only necessary in connection with the work of forecasting storms, more especially in Europe, where the cloud indications are especially valuable. Such exact observation is however not necessary for the sailor in the Tropics. These two meteorologists suggest that ten terms compounded of the four fundamental types, cirrus, stratus, cumulus, and nimbus (introduced years ago by Howard) are sufficient for ordinary practical purposes. Howard's method of naming clouds according to their forms was in the opinion of these meteorologists satisfactory so far as it went, but it failed to take into account their relative heights. The following gives Professor Hildebrandsson's scheme :—

A.—Clouds in connection with the general movements of the air—

(1) Fine weather clouds—

(*a*) Highest fine clouds, probably over 30,000 feet in height—

(1) **Cirrus**—in form of feathers, &c.

(2) **Cirro-stratus**—in form of fine, thin veil, often with halos, &c.

(*b*) Fine weather clouds of round forms and often with intervals of blue sky, including—

(3) **Cirro-cumulus**—in form of small, snow-white balls, usually at elevation of about 20,000 feet.

(4) **Alto-cumulus**—in form of larger and cotton-like balls, at elevation of about 12,000 feet.

(5) **Strato-cumulus**—in form of great, grey, rounded masses, at elevation of about 6,000 feet.

(2) Bad weather clouds, including flat clouds, stretched out as a veil—

(6) **Cirro-stratus**—in form of a thick greyish or bluish sheet of cloud, usually at elevation of about 15,000 feet.

(7) **Nimbus**, or rain cloud—in form of dense masses of dark clouds, with fringed edges.

B.—Clouds due to condensation in the lowest strata—

(8) **Stratus.**—Mist floating in the air, at an elevation of less than 4,000 feet, and not resting on the ground.

C.—Clouds formed by ascending currents—

(9) **Cumulus.**—As rounded masses, with flat bases.

(10) **Cumulo-stratus.**—Vast rounded masses, towering up like mountain ranges or as gigantic mushrooms, with a flat layer of cirrus around or on the top.

Abercrombie's classification of clouds.—The following is Abercrombie's arrangement :—

A.—High clouds (usually at an elevation of over 12,000 feet)—

(1) Cirrus.

(2) Cirro-stratus.

(3) Cirro-cumulus.

B.—Middle clouds (usually at an elevation of between 6,000 and 12,000 feet)—

(4) Strato-cirrus.

(5) Cumulo-cirrus.

C.—Low clouds (usually at an elevation of less than 6,000 feet)—

(6) Cumulus.
(7) Stratus.
(8) Strato-cumulus.
(9) Nimbus.
(10) Cumulo-nimbus.

HIGH CLOUDS.

Cirrus in its pure and simplest form consists of wisps of hairy or feathery cloud. Cirrus is not very common in the Trades or near the Equator, but very frequent in higher latitudes.

Cirro-stratus is a thin veil of wispy cloud, flatter than pure cirrus, and usually more or less mixed with a light formless haze of ice dust. The varieties are very great, and there are great discrepancies in naming these forms among various observers.

Cirro-cumulus.—This is a thin, high cloud, more or less in detached masses, with a characteristic fleecy structure, like lamb's wool. It occurs all over the world, and is common in all latitudes.

MIDDLE CLOUDS.

Strato-cirrus.—This is simply a denser and lower form of Cirro-stratus, but the word Strato is put first to give the idea of its being lower than cloud Cirro-stratus. This cloud is very common in the Tropics.

Cumulo-cirrus.—Fleecy cloud. This in form alone is identical with the before mentioned Cirro-cumulus; it is usually denser and thicker, and is always at a lower level. It is introduced simply as an easy way of expressing low Cirro-cumulus, by putting the word Cumulo first. "Mackerel sky" may be either Cirro-cumulus or Cumulo-cirrus, but the detached masses, though flat, have not the characteristic fleecy structure of Cirro-cumulus. This is a very rare cloud, if the term be restricted to small, non-fleecy patches of cloud. "Festooned Cumulo-cirrus" is a dense form of Cumulo-cirrus in which the component nubecules, though at a middle level, are so heavy as to droop, and present a base, rounded downwards. When in the Tropics they catch the reflection of a purple after-glow, and appear to hang like pink grapes in a transparent sky; they are among the most beautiful of clouds.

LOW CLOUDS.

Strato-cumulus.—This is another cloud form, to which a variety of names are applied by different observers. The term should be applied to a low-level cloud, too lumpy to be called pure stratus, but not composed of the rounded, flat-based masses of true cumulus. This cloud is found all over the world. Sometimes in the Tropics the masses of cloud are so arranged that, when seen in perspective near the horizon, they look like parallel bars of cloud. This is the kind to which the term Roll-cumulus has been applied by the British Meteorological Office.

Cumulus or Rocky cloud.—This in its pure form is a detached cloud, with a flat base and a rocky top, and may vary from a small nubecule to a mountainous mass. This is one of the commonest clouds everywhere, but becomes less frequent the further we proceed Polewards. A particular form of cumulus may be described as Festooned cumulus. This is a cumulus whose base hangs down in festoons. It is tolerably common in Great Britain under the popular names of "Pocky cloud," or rain balls, and is very common in the Tropics.

Stratus.—This is a word which is used in a most promiscuous manner by different observers for all sorts of low-level clouds. Some apply it to pure fog, others to fog when it has lifted off the ground, and others to a low sheet of thin flat uniform cloud. The forms are really so various that probably the two latter, which are often indistinguishable should be called stratus. Stratus occurs all over the world, but is more common out of the Tropics than near the Equator.

Nimbus.—This is also a kind of cloud about which observers differ very much. Theoretically every cloud from which rain falls should be called Nimbus; but in practice all over the world rainfalls from two distinct types of cloud, *viz.* from a stratiform cloud something like that which has just been called Strato-cumulus; and from a mountainous cumulus. The former is characteristic of extra-tropical cyclone fronts; while the latter is distinctive of thunderstorms, the bulk of rain in the Tropics, and the whole of that on the Equator and in the Doldrums. The word Nimbus should be restricted to rain-giving stratiform clouds, and to all the class of clouds known as scud, raggy cloud, Fracto-cumulus, &c., which are formed under a dark canopy of rain cloud, even when it is not possible to see whether the summit of the cloud is flat or rocky.

Cumulo-nimbus.—This term is restricted to the mountainous cumulus which discharges rain in showers and thunderstorms. The word has the advantage that it practically defines the nature of the rain, whether cyclonic or not; and, also, that it practically separates the cumulus of a fine day from the similar cloud of a showery day.

Cumulo-stratus.—Sometimes a flat stripe is seen crossing a Cumulo-nimbus, or the top of that cloud seems to stretch out flat as if a stream of air impinged against a flat wall till the whole looks like a mushroom, or else a peculiar hazy, slightly hairy layer of cloud seems to form on the top of the Cumulo-nimbus. How far these appearances are simply the effect of one cloud seen in perspective against another, or how far they are a development of the cumulus itself, need not be considered here. The appearance is a well-known associate of showers and thunderstorms from the Doldrums to Northern Europe.

CHAPTER II.

PHENOMENA OF CYCLONIC STORMS AND CYCLONES IN THE BAY OF BENGAL CHIEFLY CONSIDERED AS STORM INDICATIONS.

Preliminary Remarks on Cyclonic Storms.—In the preceding chapter, the more important principles and facts of the science of meteorology have been explained for the use of mariners, so that they may use the meteorological instruments generally found on board to greater advantage than hitherto when navigating the Bay of Bengal, and also may be enabled to understand weather charts and obtain, from an inspection of them, information of the general character of the weather over a large area. In the present chapter we deal with the chief object of the book, *viz.* the more important features and peculiarities of cyclonic storms in the Bay of Bengal, and more especially those features which can be observed by a sailor and employed as indications to determine the probable character, position, and track of any cyclonic storm he may encounter when navigating that sea.

It has been explained in the preceding chapter what is meant by a barometric depression and what by a cyclonic circulation. We have also stated that in an area of barometric depression (that is, an area in which the barometer stands lower than in neighbouring districts and gradually rises outward from some central position in all directions) the air moves invariably in a particular direction and manner round this central position, and that such an air motion is technically called a cyclonic circulation. Frequently, the air motion in such a circulation is feeble and winds light. There is, however, under favourable conditions in the Bay of Bengal, a marked tendency for a cyclonic circulation when established to become stronger and more vigorous; when this is the case, the cyclonic circulation may gradually develop into a cyclonic storm. *All large storms in the Bay of Bengal are cyclonic circulations: all cyclonic storms are of more or less gradual growth and commence as feeble circulations.* Hence cyclonic circulations in the Bay are of very varying strength or intensity, as well as of magnitude. It is of course not possible to draw hard-and-fast lines in such matters. Hence cyclonic circulations and cyclonic storms differ in two elements—extent and intensity. In the area covered by a cyclonic storm, the winds increase in force from the outer limit to the centre or the central calm area (if there be one): over a portion of this area nearest the centre, winds of force 7 and 8, upwards to 12, prevail. This inner area forms the storm area of strong to dangerous winds. The size, or greatest width, of this area gives a rough measure of the magnitude or extent of the storm.

The intensity is best and most easily measured by the depth to which the barometer at the centre falls. The simplest standard of reference is the ordinary or normal height of the barometer at the time. The difference below this and the actual height of the barometer at the centre gives a rough practical measure of the intensity of the storm.

The intensity and magnitude of cyclonic storms appear to be, to a very considerable extent, independent of each other. Thus, it is not only possible

to have a storm of considerable extent but of very feeble intensity, but it is also possible to have a storm of small extent, and of great and even extraordinary intensity. The most intense storm in the Bay of Bengal on record is the False Point cyclone of September 1885, in which the barometer at the centre was approximately 2¼ inches lower than usual at that period of the year. The largest, as well as one of the most intense, storms in the Bay was the Backergunge cyclone of October 1876.

The storm area in the case of the largest and most intense cyclones may be divided into two portions: an outer and an inner storm area. In the outer storm area, the barometer falls slowly and to a moderate extent, and the winds are of force ranging from 6 to 9 or 10, the strongest winds being experienced in the squalls.

In the inner storm area the barometer falls with excessive rapidity from the outer edge to the central area (which is in the Bay of Bengal an area of calms), or baric gradients are excessively steep, the winds of hurricane force, the shift of wind rapid, and the sea very high, confused, and dangerous. The most remarkable feature of this inner storm area is a small central area, usually known as the calm centre, or bull's eye of the storm, in which there is little or no wind and cloud, the sun or stars are usually visible through a thin veil of mist, and the sea pyramidical and boiling like a cauldron.

The reader should hence remember that in the most vigorous cyclones of the Bay of Bengal the storm forms only a portion (the inner portion) of a cyclonic circulation. In the outer portion of the cyclonic circulation, the winds are governed by the indraught to the storm area, but are of moderate force, and not of sufficient intensity to be considered as stormy winds. The inner portion of such a cyclonic circulation includes:—

(1) The outer storm area in which winds of force 6 to 9 prevail.
(2) The inner storm area in which winds of force 10 to 12 prevail.
(3) The calm central area.

The ratios of the magnitude of these differ very greatly in different storms.

By far the larger proportion of cyclonic storms which occur in the Bay are of small extent and moderate intensity. In these storms there is no calm centre, and rarely an inner area of hurricane winds. The weather, sea, and winds in these storms are such as occur in the outer storm area of the severe and dangerous cyclones described in the preceding paragraph. Cyclonic storms of sufficient extent and intensity to be dangerous occur in the Bay only during the period that south-west winds are blowing more or less steadily over the entrance and south of the Bay—that is, from the beginning or middle of April to the end of December. This period will for convenience be called the "cyclone season." Cyclonic storms may occur in the Bay at any time during this period. The character of the storms varies to some extent during this period, being dependent on the general weather conditions prevailing at the time of their origin.

As is well known to sailors, during the months of January and February, steady and moderate north-east winds and fine clear weather usually prevail in

the Bay. These north-east winds of the north-east monsoon are analogous to the corresponding winds of the north-east trades. In the beginning of March, with the rapid increase of temperature in Northern and Central India, local sea-winds commence at the head of the Bay and strengthen. These winds back down the Bay to some extent in April. During this period of gradual change from the prevalence of dry land winds in the interior to the setting in of the humid winds of the south-west monsoon period, which is called the May transition period, the north-east winds in the Bay become feebler and are replaced by light, unsteady, variable winds in the centre of the Bay in April and May. This continues until the latter part of May or beginning of June, when, after one or two preliminary feeble efforts, the true south-west winds of the south-west monsoon advance rapidly up the Bay, and shortly afterwards penetrate into Burma, Bengal, and gradually into Upper India.

This change introduces the south-west monsoon winds, and rains proper into India, which last until about the middle or end of September. After this the rain-giving winds retreat and tend to back down the Bay. The retreat of these winds in the Bay, unlike their advance, is a very slow process and continues until about the end of Decemher. In consequence of the peculiar conditions then prevailing in the Bay, the south-west winds still blowing over the south of the Bay curve through south, south-east and east, and thus reach the Coromandel coast as north-east damp winds, and give for a period of about two months heavy rainfall to Southern India. The commencement of these rains in October in Southern India is usually termed the beginning of the north-east monsoon, but the rains ought really to be thought of and called "late south-west monsoon rains." This period of slow change from the prevalence of the south-west monsoon over the whole of India to its final retreat from the Bay is, for convenience, called the October transition period. The division of the year described above is hence as follows:—

(*a*) North-east monsoon period, from 1st January to middle of March, characterized by fine weather and absence of cyclonic storms in the Bay.

(*b*) May transition period, extending from 15th March to beginning of June, characterized by occasional advances of south-west monsoon winds in the south of Bay, and terminated by the general advance and establishment of the south-west monsoon.

(*c*) South-west monsoon period, from 1st June to 15th of September, or period of general rain in India due to the prevalence of steady south-west winds over the whole of the Bay, the Arabian Sea and India.

(*d*) October transition period, from the 15th of September to the end of December, marked by decay and retreat of the south-west current in Bay, and terminated by its final disappearance.

The experience of many years has shown that during the south-west monsoon period proper, *i.e.* from 1st June to 15th of September, there is a rapid succession of cyclonic storms of moderate extent and small intensity. These are the storms of the rains proper. In many cases they form quite close

to the south-west of the Sunderbuns, and their only prominent feature which comes to the notice of sailors is the very strong westerly winds which blow in their southern quadrant or near the head of the Bay. Hence they are sometimes described as westerly gales, but it should be remembered that they are in all respects cyclonic storms.

During the May and October transition periods, storms on the whole occur less frequently than during the rains proper. The majority of the storms of these two periods are of moderate extent and intensity, but occasionally they develop into storms of great extent or intensity. A rough calculation, based on the experience of the past twelve years, shows that about one out of three cyclonic storms which occur during these periods, is a fierce and dangerous cyclone with an inner storm area of hurricane winds and a calm centre.

There is hence a very marked distinction between the smaller cyclones, which are of frequent occurrence during the whole cyclone season, and more especially during the rains proper, and the intense cyclones which are of very occasional occurrence and only during the transition periods.

It has already been pointed out that cyclonic storms form gradually, and if conditions are favourable increase in intensity until they become fierce and dangerous storms.

The order of growth of a cyclone is—

(1) Squally weather, with irregular winds.

(2) Squally weather, with cyclonic circulation of moderate intensity.

(3) Intensification of the cyclouic circulation, commencement of hurricane winds near the centre and the development of calm centre.

We now proceed to give a brief discussion, with illustrations from recent information contained in the copies of the meteorological logs of vessels sent in to the Calcutta Meteorological Office, of some of the more important phenomena of cyclones, more especially those which can be used as indications of their existing position and line of march.

This is followed by a detailed account of cyclone distribution and of tracks as dependent upon the weather conditions of the period, and, finally, by a full discussion of the relations of the wind directions in different parts of the storm area to the bearing of the storm centre. In the concluding summary it is shown how from any given indications the existence of a cyclonic storm can be frequently judged, and from wind and other observations its probable bearing and course can be discovered.

Character of the weather and sea disturbance in the smaller storms of the rains proper.—The character of the smaller cyclonic storms of the rains has been to a certain extent already described. They may occur at any time between the beginning or middle of June and the middle or end of September The barometer at the centre is rarely more than two or three tenths of an inch below the normal pressure of the period. Judging from the experience of the past twelve years they never have a well-marked calm centre. The winds to the north, north-west and west of the centre of wind convergence are comparatively feeble. For example, in the storm of July 1883, when hurricane winds of force 11 and 12 were blowing at the Sandheads, over which the centre was slowly

drifting, the force of the northerly winds at Saugor Island, 50 miles to the north, at the same time, was only 3 to 4. In these small storms strong cyclonic winds are only experienced in the great majority of cases in the south and east quadrants. Hence the cyclonic nature of these storms was for many years overlooked and they were regarded simply as westerly gales. This was of course due to the fact that they formed near the head of the Bay, and hence the only marked feature of the storm which came under the notice of sailors was the strong westerly and south-westerly winds which prevailed in the centre and north of the Bay during the storm and for some time after its passage inland. They are, notwithstanding, true cyclonic storms, with a centre of indraught exactly as is the case in the cyclones of October and November, and the same rules for the determination of the centre and line of march apply as in the case of other cyclonic storms in the Bay. As the barometric depression at the centre is small and the storms are of small extent, they are never accompanied with storm-waves, such as frequently cause in the case of the October cyclones so much destruction of property and loss of life in the low-lying lands at the head of the Bay.

The sailor in the Bay of Bengal should hence realize fully the cyclonic nature of these storms. As they usually form near the head of the Bay and pass in the great majority of cases across the Orissa coast, they are occasionally very trying to vessels proceeding from the Hooghly southwards. The chief indication of the formation of one of these storms on the Orissa and South-west Bengal coasts is the suspension of the ordinary south-west monsoon winds and the setting in of north-east or east winds (described in pages 75-76), and of comparatively fine and dry weather in the midst of the rainy season.

If a vessel leaves the port of Calcutta and proceeds down the river during the months of June, July, August, or September, while these unusual conditions prevail, *viz.* light north-east or variable winds, with fine, bright, sultry and comparatively dry weather, the sailor may be almost certain that there is dirty weather at the head of the Bay. It may be no more than squally weather, or it may be a severe storm of the rains. It should, however, be remembered that as these storms are small, they may give rise to more rapid shifts of wind than the larger storms of the October period. The wind and sea in the southern and eastern quadrants are frequently almost as dangerous and trying as in the larger cyclones of the October period. Hence the captain of a vessel about to go to sea from the Hooghly in such suspiciously fine weather in the rainy months should hesitate to proceed unless he is fully prepared to weather a storm. The storm may be a feeble one, but on the other hand it may be one which he may find it difficult to escape from if it overtakes him in the confined north-west angle of the Bay.

The following descriptions of the weather experienced in these storms during recent years are extracted from the logs of vessels sent in to the Meteorological Office, and will show that the weather and sea in such storms may be of cyclonic force, and very dangerous.

The log of the ship *Craigburn* thus describes the weather experienced in a small storm at the head of the Bay on 15th June 1886:—

"10 A.M.—Terrific squalls, with terrible confused sea. NOON—Gale appa-

rently increasing, if possible. Squalls appalling, with terrible lightning and occasional peals of thunder. Sea running mountains high in all directions."

The log of the P. S. *Cassandra* describes the weather she had in the same storm as follows :—

"Vessel commenced driving on account of the terrific sea and very heavy squalls in rapid succession."

The log of the ship *Airlie* describes the same storm as follows:—

"8 P.M.—Blowing fiercer than ever, the wind roaring like heavy thunder. The squalls were so heavy and accompanied with such blinding rain that it was an impossibility to see the fore part of the ship. 11 P.M.—I think that this is the time it blew hardest. You could scarcely move on deck, as thecy clone blew with such fearful force and the squalls were really something awful. The rain seemed to come down in one solid body."

The following gives an account of the weather as experienced on board the floating light-vessel *Canopus* during a small storm in the fourth week of September 1887 :—

"*September 23rd.*—At 8 P.M.—Rapid succession of blinding, and very heavy rain squalls, attended with violent lightning and thunder. 10 P.M.—Blowing a very heavy gale, with almost continuous heavy rain, squalls, and vivid lightning and thunder. MIDNIGHT.—Wind still increasing, accompanied by most terrific rain, squalls of full cyclonic force, and vivid lightning. Nasty cross sea getting up.

"*24th.*—Commenced with hard gale, accompanied by most terrific heavy rain; squalls of full cyclonic force and most vivid lightning * * * * About 10 A.M. it blew with most terrific force, accompanied by most blinding heavy rain and very vivid lightning, and the sea now became a perfect seething mass of foam."

The following gives a description of the weather experienced during a small but severe storm at the head of the Bay in June 1883 :—

The log of the ship *British Princess* runs thus—

"*28th June 1883.*—4 A.M.—Heavy rain, vivid lightning with thunder, high confused sea. 8 A.M.—Heavy squall with torrents of rain. NOON.—Moderate gale, high confused sea. 4 P.M.—Fresh gale, high sea and heavy rain. 8 P.M.—Heavy squalls, torrents of rain, high sea. MIDNIGHT.—Furious squalls, torrents of rain and high sea."

The log of the British India Steamer *Commilla* gives a fuller, and even more expressive, account of the weather during the same storm :—

"*28th June 1883.*—4 A.M.—Very high sea from south and south-west. 8 A.M. —Breeze very variable in force, with very hard squalls from south-south-west and rain. NOON.—Very high sea running from south-south-west. 4 P.M.—Very high sea from south-west, and hard squalls from south-south-west. 6 P.M.—Breeze very unsettled and hauling to north-west at times. 6-30 P.M.—Very heavy wind and rain, tremendous sea from south-south-west and south-west. 7-30 P.M.—Terrific sea carried away starboard cutter. 8 P.M.—Terrific squalls from south-west and very high sea. New jib and staysail split.

"*29th June 1883.*—4 A.M.—Terrific storm, continual rain and furious squalls. 8 A.M.—Squalls of hurricane force ; mountainous sea. NOON.—Very high and

dangerous sea running; both anchors lifted out of catch-hooks, breaking one stock. 4 P.M.— * * * Violent squalls from south-west. 8 P.M.—Sky overhead clearing at times; very dark, wild, squally weather; very heavy rain in the squalls."

The log of the Ship *Pemba* describes the same storm briefly:—

"*29th June 1883.*—Fierce gale, with high, irregular sea, and hard squalls, blowing with hurricane violence. * * * * Sea breaking over the ship fore and aft."

It is not necessary to multiply these descriptions, as the previous extracts have shown that very stormy dangerous weather and winds of hurricane force may be experienced in these small storms.

Even more dangerous weather occurs in the case of the small, but very intense cyclones that occasionally form at the commencement of the October Transition period and advance to the north-west angle of the Bay.

The following extracts from the logs of vessels that encountered the False Point cyclone of September 1885 are given. This was a very small storm, which in all its more important features resembled the fierce October cyclones which occasionally occur, but which happened very early in the season.

Ship *Governor Wilmot*, 20th September, in Lat. 14° 45′ N. and Long. 92° 20′ E.—

"4 A.M.—Whole gale; furled foresail and fore and main topsails; * * * blowing very hard. 8. A.M.—Regular hurricane; sky black; thick clouds, low; sea rough, breaking on board; constant heavy rain. Barometer very low. Sky thick and black; at noon more like night."

Ship *Kunt Alfasson*, 21st September, in Lat. 17° 04′ N., Long. 87° 04′ E.—

" * * * Later on the wind continually freshened to a terrific gale * * * * * Rain pouring down continually in immense quantity all the time without ceasing, and the gale blowing in terrific puffs; * * * * the sea very turbulent and high, and the barometer continually going down."

Ship *Quang Tung*, September 21st, Lat. 19° 53′ N., Long. 89° 10′ E.—

"9-45 A.M.—Wind and sea rapidly increasing; very heavy south-easterly sea. NOON. Very heavy sea. 3 P.M.—Very hard squalls from the eastward, with a very heavy sea. 4 P.M.—A heavy sea struck the port forward sponson house, smashing it completely in, washing away engineer's bath-room, &c. 8 P.M.—Very hard squalls from the eastward; heavy sea and swell. MIDNIGHT.—Very heavy confused sea."

Ship *Calcutta*, 21st September, in Lat. 16° 50′ N., Long. 89° 32′ E.—

"The sea all this time seemed to come from all quarters. Heavy spray coming on board first from one place and then another."

Ship *Clan MacIntosh*, September 21st in Lat. 19° 35′ N., Long. 86° 47′ E.—

"MIDNIGHT.—Strong gale, with terrific squalls and torrents of rain and wind blowing at times with hurricane force. Wild confused sea."

Ship *Britannia*, 21st September, at noon, in Lat. 20° 21′ N., Long. 87° 25′ E.—

"MIDNIGHT.—Blowing a hurricane, much lightning. From 1 to 3 A.M. it blew in terrific squalls, and * * * so much rain falling we could not see the masts and yards."

Character of winds to the north and west of cyclonic storms in the Bay of Bengal during storms of the rains proper.—It has been pointed out more than once that the most important feature in cyclonic storms is the strong south-west moist winds which feed into them. Hence it becomes important to know the chief features of the south-west monsoon winds, as it is probable that cyclones may in part at least depend upon changes in that current. The observations of recent years, both on land and at sea, prove that the south-west monsoon is much more variable than was formerly supposed. It is not a steady air-current like the south-east trades in the Indian or Pacific Ocean. It appears, on the contrary, to go through a series of pulsations. During the first part of each of these periods it advances in force into the interior and gives general rain for some time. Afterwards it appears to weaken and backs down the Gangetic plain, and the strong rain-giving winds in Northern India are replaced for a short time by light unsteady winds. This is followed by another advance, and so on throughout the whole monsoon season. These variations of strength and alternations of advance and withdrawal form the most conspicuous and one of the most important features of the south-west monsoon in Northern India.

It is found that almost without exception, during the rains proper, all the cyclonic storms that are generated during the period between the 15th of June and 15th of September form in the intervals between the partial retreat and advance of the monsoon current. They hence appear to commence to form in front of an advancing rush of moist winds, and, as they march across the coast into the interior, they carry the damp winds and rain with them. They are hence one cause of the very unequal way in which the rains are frequently distributed during the south-west monsoon in Northern India, as these storms draw the rain away from other districts to distribute it in large amounts over the narrow belt along which they advance. These storms of the rains, as have been pointed out more fully in page 72, are almost invariably of small intensity, as measured by the barometric depression, and generally give moderate cyclonic winds, although occasionally (in about one storm out of five or six) they are attended with winds or squalls of hurricane force near the centre at sea.

These facts will enable the character of the winds in the west quadrant of the cyclonic storms of the rains proper to be understood. Before they commence to form, and whilst they are forming, the regular southerly winds of the season are to a large extent suspended in Bengal and at the head of the Bay. Light unsteady winds prevail, and the weather is sultry and oppressive. A rush of strong monsoon winds commences in the centre of the Bay, drawn or pressed forward by some force. Squalls begin to occur and increase in frequency and intensity, and a small whirl (perhaps) begins to form. If this be the case, the whirl thus started, after some time varying very considerably in length according to circumstances, advances landwards and carries heavy rain with it to the districts over which it passes.

It is hence the winds in the southern and eastern quadrants which bring up the energy that starts and maintains the storm. They are, moreover, the normal winds of the season, intensified locally by the cyclonic indraught.

The winds in the western quadrant are abnormal winds, with little or no energy, dragged into the storm.

The following descriptions of the winds at the head of theB ay just before these storms, as experienced by vessels, are extracted from their logs :—

Ship.	Time.	Distance and bearing of centre of cyclonic storm.	Remarks.
S. S. *Argo* . .	13th June 1886 .	Storm forming 130 miles E. N. E.	Winds flying all round the compass.
Foyle . . .	13th June 1886 .	Storm forming 80 miles S. E.	Baffiing winds in all directions, with calm intervals.
Duke of Edinburgh	14th June 1886 .	130 miles E. .	Variable winds, from all quarters.
Star of Albion .	26th June 1883 .	230 miles E. N. E.	Light northerly winds, but winds very unsteady in force and direction.
St. Magnus . .	26th June 1883 .	160 miles E. by N.	*Morning.*— Faint airs and calms. *Afternoon.*—Almost calm ; wind at times, but variable, gusty ; rain in torrents.
Janet Cowan .	18th July 1882 .	35 miles E. by S. .	Wind very unsteady, shifting all round the compass.
Mira . . .	18th July 1882 .	100 miles N. E. .	Light N. E. winds of force 2.
S. S. Herat . .	6th Sept. 1882 .	200 miles N. E. .	Light N. E. winds. Weather generally fine, with rain ; clouds about, but much rain (light misty, drizzling rain) ; clouds forming and then disappearing altogether before reaching the ship). Heavy bank to south-east.

These cases, selected from a large number, illustrate the character of the winds in the north-west angle of the Bay before and during the approach of a small cyclonic storm of the rains proper. The winds shift round to the north-east and form a part of the cyclonic circulation which is being established. They are, however, generally very light and unsteady, and are of little or no importance so far as the maintenance of the cyclonic circulation is concerned. They, moreover, stand in the most marked contrast to the winds which prevail in the opposite quadrant. Sailors should recognize fully that light and unsteady north-easterly airs, such as described above, in the north-west angle of the Bay during the monsoon months of June, July, August, and the first half of September are an almost certain indication that a cyclonic storm is forming or is in existence in the north of the Bay.

Character of winds to the north and west of cyclonic storms of the Transition periods.—The circumstances are different during the formation of storms in the May and October transition periods. During these two periods the south-west monsoon is not in full possession of the Bay. In the first or May transition period the south-west monsoon has not advanced up the Bay, and hot-weather conditions prevail in Bengal and at the head of the Bay. In the latter, or October transition, period it is retreating down the Bay and the (so-called)

north-east monsoon is setting in on the Coromandel coast. The character of the winds in these two cases differs slightly at the head of the Bay immediately before the advent of a cyclone. It may be premised that these cyclones are occasionally very extensive and fierce storms. In the inner central or storm area the winds are governed by the cyclone only, and show that rotatory motion, combined with indraught to the centre, which is the essential feature of rapid cyclonic air motion. The winds are, however, in all cases influenced more or less to a very considerable distance away from the inner storm area. If the cyclonic storm be at a considerable distance from the place of observation and the wind that is slightly influenced by its action or indraught be the normal wind of the season, its only effect will be to strengthen that wind, which will hence be apparently normal in character, but steadier and stronger than usual. Hence it may happen that a wind from such a direction, which is usually a fair-weather wind, may under these conditions blow directly into a cyclonic storm. This is especially the case in the cyclones of the months of October and November at the head of the Bay.

The winds that then prevail at the head of the Bay are from north with more or less easting. The following tables give the mean wind directions at the more important ports on the coast of the north of the Bay for all the months April to December:—

Mean Wind Directions.

	Akyab.	Chittagong.	Saugor Island	False Point.	Gopalpore.	Vizagapatam.
April	S. 75° W.	S. 12° W.	S. 20° W.	S. 38° W.	S. 5° W.	S. 48° W.
May	S. 33° W.	S.	S. 12° W.	S. 31° W.	S.	S. 41° W.
June	S. 2° E.	S. 31° E.	S. 15° W.	S. 45° W.	S. 12° W.	S. 58° W.
July	S. 4° E.	S. 40° E.	S. 24° W.	S. 59° W.	S. 16° W.	S. 74° W.
August	S. 1° E.	S. 32° E.	S. 17° W.	S. 57° W.	S. 9° W.	S. 74° W.
September	S. 9° E.	S. 29° E.	S. 4° W.	S. 25° W.	S. 6° W.	S. 60° W.
October	S. 35° E.	N. 10° W.	N. 10° E.	N. 40° E.	N. 41° E.	S. 65° E.
November	N. 6° W.	N. 20° W.	N. 5° E.	N. 22° E.	N. 29° E.	N. 75° E.
December	N. 15° W.	N. 23° W.	N. 7° E.	N. 43° E.	N. 44° E.	N. 83° E.

The following table gives the directions in the preceding table to the nearest points of the compass for the information of sailors:—

	Akyab.	Chittagong.	Saugor Island.	False Point.	Gopalpore.	Vizagapatam.
April	W. by S.	S. by W.	S. S. W.	S. W. by S.	S.	S. W.
May	S. W. by S.	S.	S. by W.	S. W. by S.	S.	S. W.
June	S.	S. E. by S.	S. by W.	S. W.	S by W.	S.W. by W.
July	S.	S. E.	S. S. W.	S.W. by W.	S. by W.	W. by S.
August . . .	S.	S. E. by S.	S. S. W.	S.W. by W.	S. by W.	W. by S.
September . . .	S. by E.	S. E. by S.	S.	S. S. W.	S. by W.	S.W. by W.
October . . .	S. E. by S.	N. by W.	N. by E.	N. E.	N. E.	E. S. E.
November . . .	N. by W.	N. N. W.	N.	N. N. E.	N. E. by N.	E. by N.
December . . .	N. by W.	N. N. W.	N. by E.	N. E.	N. E.	E. by N.

The preceding tables require for exact information to be supplemented by another showing the amount of shift which takes place in the wind direction during the day. This can only be given for Chittagong, Saugor Island, and Rangoon, at which there are continuous wind-registering instruments.

It will be sufficient to give it for the month of October only, in connection with the present subject—

Mean Wind Direction at various hours during the day in month of October.

Station.	Mean Wind Direction.					
	4 A.M.	8 A.M.	Noon.	4 P.M.	8 P.M.	Midnight.
Chittagong . . .	N. 31° E.	N. 46° E.	N. 54° E.	W.	S. 86° W.	N. 5° E.
Saugor Island . .	N. 27° E.	N. 6° E.	N. 38° W.	N. 50° W.	N. 13° E.	N. 88° E.
Rangoon . . .	S. 27° E.	S. 57° E.	S. 68° E.	S. 16° E.	S. 7° W.	S. 6° W.

The first two tables show that at the mouth of the Hooghly and in the north-west angle of the Bay the mean or ordinary wind direction is between north and north-east in October and November. There is considerable shift in the direction of the wind during the day at the coast stations due to the heating of the land. How far this extends seawards, and to what extent the winds are modified in the open sea in the north of the Bay, can only be surmised at the present time, as the data for the discussion of the changes of wind during the day over the sea area are too limited to give reliable results. It is, however, almost certain that the winds in the north-west angle of the Bay shift through at least two or three points during the day, veering near the coast from east of

north to west of north during the afternoon, and backing during the night and early morning from west of north to east of north.

The winds in November over the north of the Bay are similar in character, and are practically from the same direction as in October. They are, on the whole, slightly stronger and steadier. Hence the preceding remarks apply equally to the month of November, and also to the first-half of December.

These, then, are the normal steady winds of the months of October and November, which are emphatically the cyclone months in the Bay. If a cyclonic whirl forms at that time in the Bay, it is usually generated in the centre of the Bay, and advances in some direction between north-east and west, the average direction being north-west. The tendency of such a whirl is to produce north-east winds in the north-west quadrant, or in the north-west of the Bay, and also to cause them to shift round to east if the cyclone takes a north-west or west track.

Hence the effect of the distant cyclone is generally (*i.e.* in at least two cases out of three) to strengthen the north-east winds and give them a tendency to veer to east, and also increased steadiness, and so long as the centre is at a considerable distance, the weather is fine and bright, and atmosphere frequently unusually clear. Hence it may be that when these winds are apparently most favourable for a ship outward bound from the Hooghly and the weather also even finer looking than usual, they are really feeding into a cyclonic storm further south.

They are in this case exceptionally treacherous and dangerous, as they may carry a ship southwards in front of an advancing cyclone, where she would not have sufficient sea-room to be able to manœuvre and escape from the inner storm area.

It will thus be seen that north-east winds at the head of the Bay, and more especially in the north-west angle of the Bay, during the months of October and November, may indicate entirely different weather conditions. They may be—

1st.—Merely the normal winds of the season and accompany fine clear weather in the north of the Bay and in Bengal, and either fine or squally weather, with rain, in the south of the Bay, more especially in the neighbourhood of the Coromandel coast. In this case they are generally light, and shift through two or three points during the day in consequence of the heating of the land by day and its cooling by night.

2nd.—If these north-east winds are stronger and steadier than usual this may be due to one of the two following causes :—

(*a*) A stronger north-east monsoon than usual on the Coromandel coast and in Southern India. In this case weather is usually showery, with much rain and strong winds in the Carnatic, and squally in the Bay of Bengal off the Coromandel coast. During such a period pressure is frequently unusually high in Northern India, and fine, clear weather with moderate west or north-west winds prevails in Bengal and the Gangetic plain.

(*b*) The formation and existence of a cyclonic storm in the centre or south of the Bay. In this case the weather is generally unusually fine and the air remarkably clear.

The following are descriptions of the north-east winds which have prevailed at the head of the Bay, during the formation and northward movement of two or three of the largest cyclonic storms of recent years in October and November :—

First example from the Calcutta Cyclone of 1864, which struck the Bengal coast near Contai on the 5th of October.

Ship.	Date.	Distance and bearing of centre.	Remarks.
Proserpine . . .	2nd October .	580 miles south-south-east.	*Morning.*—Fine clear weather, with light winds and calms. *Afternoon.*—Wind east-north-east. Fine clear weather. Light winds. *Midnight.*—Fine and clear.
	3rd „ .	270 miles south .	*Morning.*—Wind north-east; fine and clear. *Noon.*—Weather began to change.

Second example from the Backergunge Cyclone of October 1876, which struck the mouth of the Megna on the night of the 31st October—1st of November.

Ship.	Date.	Distance and bearing of centre.	Remarks.
Tennyson . . .	26th October .	Storm forming .	She was going up the centre of the Bay at this time. Previously weather had been cloudy and showery, but on the 26th October she got into north-east winds and the weather cleared beautifully.
	27th „ .	Ditto .	Fine steady north-east breeze, with clear weather all day.
	28th „ .	358 miles south.	Fine steady breeze from north-east to north-north-east all day.

Third example from the Midnapore Cyclone of October 1874, which struck the coast near Balasore.

Ship.	Date.	Distance and bearing of centre.	Remarks.
Ireshope . . .	11th October .	Immediately before the formation of the storm.	*Morning.*—Calm and clear. 1 P.M.—Light variable airs and sultry. 8 P.M.—Wind north-north-east. *Midnight.*—Light winds and fine clear weather.
	12th „ .	Ditto .	*Morning*—Wind north-east; very light winds and clear weather. *Afternoon.*—Light wind from north-north-east and very fine clear weather.

Fourth Example from the False Point Cyclone of September 1885.

Ship.	Date.	Distance and bearing of centre.	Remarks.
P. V. Coleroon . .	20th September	450 miles south-south-east.	The weather was fine, sky unclouded, night remarkably clear. Light airs from north-east; vessels could be distinguished at a great distance.

Hence it should be carefully remembered that north-east winds in the north-west angle of the Bay are in October and November very treacherous winds, and if a captain about to leave the Hooghly and proceed southwards in either of these months sees that the wind is unusually steady from north-east and the weather remarkably fine and clear, he should consider that it may perhaps be due to, and be an indication of, a distant cyclone. He should also remember that if there be a cyclonic storm forming in the Bay, it may come up and overtake him when he is close to a lee shore. He should endeavour, therefore, to ascertain before running southwards (perhaps directly towards the centre of a fierce cyclone), from the Calcutta daily weather reports, whether any disturbance has commenced in the centre of the Bay; and if he decides to proceed on his voyage, to watch his barometer and the weather carefully, and, if the weather become suspicious, endeavour to ascertain the bearing and line of march of the cyclone that has almost certainly formed, and take the earliest precautions to avoid, if possible, being caught up by it.

General character of barometric changes during storms in the Bay of Bengal.—The remarks on this subject in the preceding chapter (*vide* pages 42 to 50) have indicated that small barometric changes are the rule in the Bay of Bengal, and that large changes are, not only the exception, but are very rare indeed. They have also shown that the small changes which accompany stormy weather in the Bay take place usually at a slower rate than the regular motions. For a fall of two-tenths of an inch in 24 hours at a given place is of very occasional and rare occurrence, whilst the total fall and rise due to the diurnal tides on the average exceeds a tenth of an inch in each of the six-hourly intervals between maximum and minimum. Hence it is that they are so rarely obscured or obliterated by the changes due to cyclonic storms. Consequently, due allowance must be first made for these regular changes, if we wish to ascertain what the irregular changes are—which are the only part that we are concerned with in determining the probable weather. Hence also exactness and accuracy of observation are as essential in the Bay of Bengal as a good barometer.

There is a belief fostered by certain descriptions (probably exaggerated) of the steady large fall of the barometer for hours and days before storms, and of the long warning it thus affords to observant mariners of the approach of severe storms given in certain works on Physical Geography.

It is certainly not the case in the Bay of Bengal. In the smaller cyclones the barometer rarely falls more than two to three tenths at any place over which

a storm passes. In the larger cyclones the barometer falls very slightly in the outer storm area of squalls and strong winds. It is only in the inner storm area—that portion of the storm which sailors should use every effort to avoid, and in which the wind blows with hurricane force—that the barometer falls rapidly.

The curves given in plate XXVII at the end of the book show far more plainly than words the character of the movements of the barometer during the passage of a large and violent cyclonic storm over a place in the Bay of Bengal or the adjacent country.

The first curve gives the barometric readings taken at hourly intervals at Calcutta during the great Calcutta cyclone of October 1864. The centre passed Calcutta at a distance of 20 to 30 miles to the west.

The second curve gives the readings taken on board the *Coleroon* during the Midnapore cyclone. She passed about 20 miles to the west of the cyclone centre. The vessel was moving during the storm, and hence the curve does not represent the same changes as would have occurred if the vessel had been stationary.

The third curve gives the readings taken at False Point Light-house (almost identical with the readings taken on board the British India Steamer the *Booldana*, which was at anchor off False Point) during the cyclone of September 1885, the calm centre of which passed over False Point.

These all show the same thing, *viz.* that the fall of the barometer is not only slow first of all, but also such as frequently occurs during slightly unsettled weather in the Bay or in India, and has no special features on the large scale such as could have given any certain and reliable indication of the approach of a deep depression and of the violent hurricane winds which prevailed during each of these storms. It is only when that portion of the storm proper, which may be termed the inner storm area, reached the observer or ship, that the barometer commenced to fall with excessive rapidity. The False Point trace is exceedingly instructive from this point of view.

To sum up the preceding remarks, all experience shows that in the larger storms in the Bay the fall of the barometer in the outer storm area proceeds very slowly and is small in amount, and is only large in the inner storm area—that area which the mariner should use every effort to avoid. In other words, the barometer in the Bay of Bengal only falls rapidly when the mariner has entered the dangerous inner circle of hurricane winds of an intense cyclone, and is hence, as ordinarily employed, not an indicator of approaching danger. This is, however, just what might be expected. The decrease of pressure, measured by the fall of the barometer, is not only caused mainly by the winds, but accompanies the violent winds and does not precede them.

The following extracts—a few out of a large number—from the logs of vessels, which include opinions of captains and pilots, will confirm these remarks:—

The commander of the *Kedgeree* pilot vessel, which was anchored at Kalpee during the Calcutta cyclone of 1864, says: "Our barometer gave no indi-

cation of anything extraordinary till the hurricane was on us, when it fell with unexampled rapidity."

Mr. W. R. Williams, pilot, writing of the Midnapore cyclone, says that "at 1 P.M. of the 15th, only a few hours before the storm passed, we had every appearance of a cyclone *except a low barometer.*"

Mr. Clarke, Magistrate of Chandbali, writing of the same storm, says: "I think the heavy wind from the east, the *high* barometer and the cross swell, ought to have warned the captain and pilot of the *Sir John Lawrence* of the cyclone that was approaching."

Mr. Wilson, speaking of the storm, says:—"The shortness of the warning given by the barometer has been noticed and is illustrated by the entries of the barometric observations taken on board the *Coleroon.* The fact that two vessels which were caught in the vortex while endeavouring to get to sea also points to the suddenness with which the storm burst over the Sandheads. The commanders of the pilot brigs, well acquainted with all the phenomena of the cyclones of the region, and perfectly familiar from long experience with all the indications of their approach, generally manage to keep their vessels at least at a safe distance from the centre of any storm which may be travelling up the Bay. It is a point of honour, however, as well as a necessary rule, to hold on to the station as long as it may appear safe to do so: as when the brigs run down to the southward it may take them some days to get back, and great inconvenience and delay may thereby be caused to vessels either outward or inward bound. In the present case the commanders of the brigs seem to have misjudged the distance of the storm, probably misled by the slowness of the fall of the barometer before they were actually within the radius of the hurricane."

The following extract is from the log of the ship *Thessalus,* which passed through the Backergunge cyclone:—

"*Tuesday, October 31st, at 4 A.M.*—There was no indication by the barometer of more than a gale or stiff breeze, but at 8 A.M., when it was too late to do anything, the gale being on us, the barometer fell considerably."

The following is an extract from a report of the weather at False Point by the light-house keeper during the cyclone of October 10th to 16th, 1882:—

"*Friday, 13th, 6 a.m.*—The weather having a very threatening appearance and the squalls blowing rather heavy, I commenced taking two hourly observations of the barometer, but as yet that instrument showed no indication of bad weather."

It is not necessary to give further extracts from logs, as the preceding illustrate sufficiently this feature of cyclonic storms and cyclones in the Bay of Bengal.

Banks of clouds.—When a cyclonic storm has formed, large masses of air are carried rapidly upwards in the body of the cyclone or over a considerable portion of the inner storm area. The aqueous vapour with which it is laden is in part condensed rapidly. Huge nimbus, pallium or rain clouds are formed from which rain is poured down in torrents. Hence, over the central area there is a permanent dense black mass of clouds which moves with, and is a part of, the cyclone. This permanent state is, of course, one of appearance or passage

only. The air, as it rises up and passes through the cloud-charged space, has a portion of its aqueous vapour condensed, and thus contributes or adds to the mass of the cloud, whilst at the same time the cloud is continually losing a portion of its mass by the rainfall. The cloud-mass is hence in a state of contant growth and decay. Its appearance at a distance is that of a huge bank of clouds resting on the horizon, which retains its form unchanged for hours. It is usually most conspicuous about sunrise and sunset. If a ship should travel at about the same rate as the cyclone, this huge bank of clouds may be observed for several days in succession. As also much electric action goes on in the body of a cyclone, due probably to the intermixture of masses of air of different states of humidity, temperature, &c., or perhaps—which appears to be more probable—to the friction of the small globules or vesicles of the condensed aqueous vapour in the earlier stages of their formation against the rapidly upward-moving air, much violent electric action goes on, more especially in these quadrants (*viz.* the eastern and northern), where the air is chiefly being carried upwards. At night the lightning is visible at immense distances. If, as is frequently the case, it may be seen by reflection from higher clouds, calculation indicates that the reflection of the lightning might be seen in this way at distances of from 300 to 400 miles under very favourable circumstances, and at distances of 50 to 100 miles under ordinary circumstances, such as are likely to occur in any storm. Hence, the appearance of a dense bank of clouds on the horizon which retains its shape for hours practically unchanged, and in which (especially at night) frequent electric action or lightning is seen, is an almost certain indication of a distant cyclonic storm. The indication is even more valuable if the same appearance be observed on two or three nights in succession. It is therefore an indication of considerable importance, and is frequently the first-marked sign of the distant formation and approach of a cyclonic storm.

The following are a few examples extracted from the meteorological information contained in the logs which have been sent in to the India or Bengal Meteorological Office.

Captain Smart, in command of the pilot vessel *Chinsurah* at the Sandheads during the great Calcutta cyclone of 8th October 1864, thus describes the bank of clouds in his private note-book—

"During the day, patches of clouds of a very deep blue, like indigo, overhead and to the eastward; 6 P.M. a very heavy bank of clouds to north-west, of a deep maroon color. First part of night inclined to be squally from east to south-east. Before I went to bed I observed very suspicious, sharp and low forked lightning to the south-east."

The ship *Lightning* passed over the centre of the Bay just before the formation of the Backergunge cyclone and advanced to the head of the Bay 150 or 200 miles in front of the cyclone, and was overtaken by it on the 31st, as she was unable to obtain a pilot to enter the Hooghly on the 28th. When in Lat. 18° 39′ N. the Captain writes in his log:—

"There has been since the 23rd a disagreeable, looking cumulus (indicative of a storm) in the south-east quarter every evening, with much lightning." On the 29th, when in Lat. 19° 38′ N., Long. 89° 18′ E., he says, "There is still that

disagreeable nimbus in the south-east quarter, with lightning going across our stern."

Several other vessels, describing this storm, speak of "the heavy bank of clouds" which they observed when they were in comparatively fine weather and at considerable distances from the storm centre.

Again, the ship *Patrie* advanced up the head of the Bay just before the Midnapore cyclone, much in the same way as the *Lightning* in the previous case. Her log of the 12th October, when she was in Lat. 17° 58′N. and Long. 88° 54′E., states, "Sky very black to the south-west, with frequent lightning;" and again on 13th October, when in Lat. 19° 27′ N., Long. 88° 34′ E.: "sky very black to south-east at sunrise."

The following description of the appearance of the distant cloud-features of the False Point cyclone as seen by S. R. Elson, Esq., pilot, from the pilot brig at the Sandheads is both accurate and interesting:—

"All this day, say from 9 A.M. to 2 P.M., the sky was comparatively clear of cloud, the surface breeze and low driving scuds being confined to a very thin stratum. Now and then smoke-like scuds would stretch up from the surface right across the wind direction, as I have observed in most cyclonic storms, more especially in those small whirls of the rainy season; the current immediately above the surface coming from about four points to the right of the wind direction. But, most remarkable, there seemed to be perfect stillness of the air strata at a small height above the hurricane wind, so far as any lateral direction was concerned, for tall tufts, or "thunder heads," as they have been termed, rose here and there, straight up towards the lofty cirro-cumulus, having level vapour planes to each, undisturbed by the indraught surface winds of the meteor. These thunder heads, or tufts, were mostly to the south-east; we had but very little rain after 9 A.M., when the wind had gone to the southward of south-east."

The following are a few of the brief descriptions extracted from recent meteorological logs:—

"There was a dark heavy bank of clouds to east and south-east; otherwise, sky was clear overhead, and to the north and west.

"The sky was one mass of heavy black clouds and rain, like a black wall to west-north-west.

"There was a heavy bank of clouds to the west-north-west. Weather assuming a very threatening appearance, with heavy wild-looking clouds to the north and north-west.

"Low cloud in the eastern horizon, with lightning occasionally.

"Clear sky overhead, but round the horizon to east, all dark; weather sultry, with heavy banks of clouds on the horizon."

The following statement gives the more important data in a tabular form, showing more especially the distance at which the cloud-bank has been observed in a few cases—

Ship.	Cyclone.	Distance and bearing of centre.	Description of cloud-bank.	Weather at time of observation of cloud-bank.
Chinsurah	Calcutta, October 1864.	375 miles S. S. E.	Heavy bank of clouds to south-east.	Fine weather.
City of Venice	Backergunj, October and November 1876.	400 miles E. N. E.	27th October.—Heavy bank on north-east horizon.	Moderate breeze, calms and light winds.
Lightning	Ditto	560 miles to S. W.	29th October 1879.—Disagreeable-looking thunder cloud in south-east with much lightning.	Variable winds, cloudy.
Japan	Ditto	400 miles E. N. E.	29th October.—Heavy bank of clouds to north.	Every appearance of a gale.
Allahabad	Ditto	350 miles S. W.	29th October,—Heavy bank of clouds to south, blue color, and very dark.	Strong south-east wind, constant rain, and heavy squalls.
P. V. Foam	Ditto	350 miles S.	30th October.—Bank of clouds to south-east and lightning.	Calms and slight sea.
P. V. Coleroon	Ditto	Ditto	Ditto	Ditto.
Patrie	Midnapore, October 1874.	115 miles S. E.	12th October, 5 A.M. to 8 P.M.—Sky very black to south-west, and frequent lightning.	Winds north-north-east, variable and north-east.
P. V. Coleroon Patrie.	Midnapore, October 1874.	200 miles, S. S. E.	13th October, day-break.—Sky very dark to south-east	Weather cloudy, and frequent lightning at different portions of horizon.
Duke of Devonshire.	Storm of October 1882.	150 miles, S. S. E.	Morning, 13th October.—Heavy bank of blue-black clouds, eastern horizon.	Heavy squalls and gale increasing; much lightning and rain.
Undaunted	Ditto	100 miles, S. S. W.	4th August.-Lightning and heavy bank of clouds to south-east.	Strong north-east wind, force 6.
P. V. Cassandra	Storm of June 1886.	...	14th June, 8 P.M.—Dark heavy bank of clouds to east and south-east with rising sea.	Weather clear overhead and to north and west, and gloomy to east.
British Provinces.	Storm of June 1883.	60 miles E. N. E.	27th June.—Heavy bank of clouds to north-west.	Distant thunder, lightning and rain.
Iolanthe	Storm of May 1884.	300 miles, E. S. E.	Sky hazy, and bad-looking to south-east.	Light winds and calm, sea very heavy.

The preceding table shows that the bank of clouds is, as might be expected, a far more prominent feature of the largest cyclones of the Transition Period than of the smaller storms of the rains. It also shows that the bank of clouds

may under favourable circumstances be seen when the vessel is at distances of 400 and 500 miles from the storm centre, and when she is in fine weather with light winds and a smooth sea. It is hence an occasional valuable indication of the existence of a cyclonic storm, more especially if it be observed in the months of May and of October and November, when skies are usually clear, except in a storm area, if one be in existence.

Sky appearances.—The air, for some time before and during cyclones, is charged with a very large amount of moisture, and is almost saturated through a considerable thickness or depth of air. The condensation of this moisture, of course, gives rise to the heavy rain that characterizes cyclonic storms. The sun's light passing through air, mixed with a large quantity of aqueous vapour, is absorbed to a considerable extent. The absorption is not the same for different colours or constituent portions of the whole sunlight, but is much greater for the green and blue than for the red.

In order to explain this action somewhat more fully, it is necessary to remind the reader that ordinary sunlight is not light of a single colour. If it were elementary and non-decomposable, it would admit of only increase and decrease in amount, such as in fact occurs every day as the sun rises and sinks in the heavens. It is really compounded of light of a great variety of colours, each existing separately, but the whole producing a single effect upon the eye, and giving rise to the impression of a single colour. By passing a narrow beam of the sun's light through a prism, the colours are separated and placed side by side. The same is effected naturally in the rainbow, the rain-drops in this case playing the same part as the prism in separating the different coloured lights and arranging them in a fixed order side by side.

It has also been found out by simple experiments that when light enters a body through which it can pass, a smaller amount of light always passes out of the transparent substance than what enters it. A certain portion of the light disappears during its passage through the body, or is, to use the proper term, absorbed, It is also found that transparent substances differ very greatly from one another in the way in which they absorb light. Some, for example, absorb all the different colored lights of which white light is composed, except that of one colour, and hence the light which passes through is of that colour only. Other substances absorb the same proportion of each of the different coloured lights, and hence the light that issues is of the same compound or resultant colour as it was before entry, but it is diminished in intensity. This is, of course, what happens when sunlight passes through a moderate thickness of good glass or of pure water or air. There are, again, other substances which absorb the different coloured elements of white light in different proportions, so that the light which issues from such a body is mixed together in different proportions to that which constitute ordinary white light, and is hence of a different colour depending upon the mixture. One substance which has this power of absorbing light of different colours in different amounts is damp air, or air containing a large amount of invisible aqueous vapour in suspension.

The sun's light is made up of violet, indigo, blue, green, orange, yellow and red light, and of these damp air absorbs the blue and green much more largely

than yellow or red. Hence, the light which comes through a great thickness of damp air contains a much smaller proportion of these colours (violet, blue and green), or what is the same thing a much larger proportion of the red and yellow rays than ordinary white sunlight, and hence appears to be a reddish colour, the depth of the tint depending partly on the thickness of the damp atmosphere passed through, which is of course greatest just before sun-set and after sun-rise, and also upon the amount of aqueous vapour in the air.

There are other effects due to the presence of very small particles of dust crystals of ice, &c., in the air, which are more difficult to explain, but these hardly concern us in this section. The colours seen in the western horizon, at and after sun-set, the irridescent colours of very thin clouds occasionally seen in India, especially near the sea, coronas, halos, &c., are due to the action of these particles in sifting light. The mariner is referred to ordinary works on meteorology for explanation on these points.

The following are a few examples of the very dark red tint that occurs under favourable circumstances before and during cyclone generation in the Bay.

Captain Keiner, the commander of the *Patrie* which passed through the area in which the Midnapore cyclone was formed 48 hours afterwards, thus describes the weather and sky appearances—

"The weather is uncertain. Winds variable from north-west to east, and squally. The sea very tranquil, but the sun blood-red on the horizon when setting. Clouds of different sizes detached one from the other passing with great velocity."

The appearance of the sky is described in the following terms in the logs of the ships *Allahabad* and *British Sceptre*, which passed up the centre of the Bay just before the Backergunge cyclone was formed, and were overtaken by it near the head of the Bay.

"*29th October.*—When the sun rose all the clouds were of a brick-dust appearance."

"*30th October.*—Very threatening appearance; moon showing with a reddish glare, tinging banks of clouds same colour."

The following are extracts from logs giving descriptions in the case of other cyclones:—

"The weather looks fine and more settled. At sun-set this evening the sky became awfully grand, a light appeared very suddenly in the east-north-east. It broke out like a large patch of red clouds, and then opened all over the heavens, making water, ship and everything on board appear red."

"The stars had a sickly appearance, and the sun rose blood-red."

"A peculiar red glare in the sky all round the compass, especially to north and west."

"The sky assumed a most strange appearance. Orange coloured and pink clouds, and a red haze about the sun. All day floods of rain."

"The sky of dark red appearance to westward and eastward." "A very red appearance all round horizon."

"The appearance at sun-set was very threatening, the sky being a bright scarlet all over."

"Dull heavy sky, with bright pink colour at sun-set."

"Sun-set sky very red-looking"

"Thick yellow haze giving a peculiar glare to the light."

This indication is, in the case of the smaller cyclones in the Bay during the rainy weather months, of little value, as reddish skies at sun-rise and sun-set will probably often be seen under the ordinary conditions of that period. They are however much rarer in the months of October and November, when the atmosphere, especially in the north and centre of the Bay, is in its ordinary state, not charged with large amounts of aqueous vapour (as it usually is in the rains). At such seasons (when the most dangerous cyclones are formed), very dark red sun-sets and sun-rises indicate that the atmosphere over a portion of the Bay is almost saturated with aqueous vapour, a state of the atmosphere such as is always highly favourable to, and precedes or accompanies cyclones. It is very valuable as an indication, as it evidently occurs either in the preliminary stages of cyclone formation, or is only visible at a considerable distance from the body of the cyclone or on the verge of the outer storm area. Hence its value as an indication when it is observed.

Occurrence of squalls before and during Cyclonic Storms.—It should be kept carefully in view by mariners in the Bay of Bengal that the formation of a cyclonic storm is a gradual process, and that it is only when the disturbance has passed beyond the initial stages that it becomes a storm in the proper sense of the word. The formation of a large storm is due to the prolonged continuance of actions, processes and changes of the same kind as those that are occurring in the atmosphere at all times when rain is falling and strongish humid winds are blowing. Whatever the causes and origin of cyclones may be, the history of all cyclones in the Bay shows that they are invariably preceded for longer or shorter periods by unsettled squally weather, and that during this period the air over a considerable portion of the Bay is gradually given a rapid rotatory motion about a definite centre. During the preliminary period of change from slightly unsettled and threatening weather to the formation of a storm more or less dangerous to shipping, one of the most important and striking points is the increase in the number and strength of the squalls which are an invariable feature in cyclonic storms from the very earliest stages. First of all, the squalls are comparatively light and are separated by longish intervals of fine weather, and light variable or steady winds, according to the time of the year. They become more frequent and come down more fiercely and strongly with the gradual development of the storm. The area of unsettled and squally weather also extends in all directions, and usually most slowly to the north and west. If the unsettled weather advances beyond this stage (which it does not necessarily do) it is shown most clearly by the wind directions over the area of squalls. The winds always settle down into those which invariably occur over an area of barometric depression or cyclonic circulation, or, in other words, are changed into the cyclonic winds of indraught to a central area of low barometer and heavy rain. As soon as the wind directions indicate that a definite centre of wind convergence has been formed in the Bay, it is also found that the centre never remains in the same position for any considerable

interval of time, but that it moves or advances in some direction between north-east and west with velocities which not only differ very considerably in different storms, but also at different stages of the same storm.

This preliminary period of unsettled squally weather may extend over several days, or may last only a few hours. It is of course impossible to define the particular hour at which the change from the antecedent disturbed squally weather to the cyclonic storm takes place. .

Hence the chief feature of this antecedent period, or first stage in the formation of cyclonic storms in the Bay of Bengal is squally weather. In those parts of the Bay where south-westerly or southerly winds are blowing, the winds are generally strong, varying in force from 3 to 6 or 7. These winds become the winds which prevail in the southern and eastern quadrants of the cyclone, if the squally weather developes, into a cyclone. In another portion of the Bay during the formation of a cyclone (always to the north or west of the area of strong southerly winds) is an area of light and variable winds (sometimes shifting in a few hours all round the compass) or of calms. But whatever the direction or character of the wind in any portion of the Bay may be, if a cyclonic storm originates and forms over it, the occurrence of occasional rain-squalls is the first indication of the commencement of disturbed atmospheric conditions, or of the threatening weather which may under favourable conditions develop into a cyclonic storm. These squalls are at first of short duration and comparatively feeble, but if they increase rapidly in frequency and intensity, they are an almost certain indication of the commencement, or of the existence of a cyclonic storm, and they become more and more prominent and more frequent and severe during the birth and growth of the cyclonic storm. It should, however, be carefully noted that squalls more or less severe occur under several sets of conditions in the Bay, and it is hence desirable to discriminate between these. This is the more necessary in order that it may be fully realized that whilst *squally weather is a necessary antecedent in time to the commencement of a cyclonic storm, squally weather is not necessarily followed by a cyclonic storm.*

Squalls of brief duration, lasting from a few minutes to one or more hours, may pass over vessels navigating the Bay due to a variety of causes. They appear to occur chiefly under three different sets of circumstances, and hence may be divided into three different kinds described in the following paragraphs.

1st.—Squalls which usually originate near the sea coast during the hot weather months of March, April, and May.—They generally occur in the afternoon or evening after the day sea winds have been blowing across the sea coast for some hours. Many of them appear to begin over the hills in Orissa, West and East Bengal. In all cases when they occur in South Bengal, clouds appear to gather in the north or north-west quarter, and gradually acquire the black, dense appearance and rounded mushroom-shape characteristic of thunder clouds. The rapid and irregular motion of these clouds, the manner in which portions of the clouds appear to be torn off from the rest, the large electrical action shown by the almost continuous thunder and lightning which frequently accompanies them, and the occasional occurrence of hail, and other features all

indicate very considerable atmospheric disturbance, which is, however, usually confined to a very small area. The disturbance apparently gathers force for some time, and then rushes down as if from a higher altitude, giving violent winds along its path, and is attended with much thunder and lightning, and frequently with heavy rain or hail. The wind veers considerably during the passage of these squalls. As they generally come down from the north-west quarter in Bengal they are usually termed Nor'-westers. These squalls appear to be of comparatively brief existence and to die away even more rapidly than they are formed. If they pass from the land to sea, they are then comparatively feeble and disappear at a short distance from the sea coast. They are hence chiefly felt in the neighbourhood of the Bengal and Orissa coasts in the months of April and May. They are occasionally very violent in the River Hooghly and the mariner should hence be on his guard in these months, especially as the first rush of the winds which accompanies them is usually very sudden, and the force of the winds is sometimes very great, nearly as great as in the severest cyclones. In a Nor'-wester which passed over Calcutta in May 1883, the velocity of the wind, as indicated by an anemometer on the roof of the Meteorological Office, exceeded 100 miles per hour in the severest gusts of the squalls. Carriages were overturned, trees blown down, and some of the ships in the river were damaged. One steamer at least was obliged to remain a day later in port in order to repair the damages caused by the storm.

An examination of the whole of the information contained in the logs of the vessels sent in to the Meteorological Office shows that they are by no means uncommon near the Sandheads and at the entrance of the river. They are, so far as can be judged from the information in the Meteorological Office, rarely felt to the south of lat. 20° N., and then only in the neighbourhood of the Arakan and Orissa and Madras coasts. At the Sandheads they occasionally come down very fiercely and raise a very rough and nasty sea. Hence it is always advisable that mariners proceeding down the Hooghly in the months of April and May, when they see a dense bank of clouds in the north-west quarter, such as is usually indicative of the probable approach of one of these squalls, should prepare for it. This, it has already been pointed out, is very advisable, because they always come down very suddenly, and the first rush of these storms is sometimes exceedingly severe.

The following statement gives brief accounts of some of these storms contained in the logs of vessels sent in to the Meteorological Office during recent years, and will assist in illustrating the character and usual time of occurrence of these storms:—

No.	Ship.	Date.	Position.	Character of squall.
1	*British Ambassador*	4th April 1883.	20° N. 87° E.	It became overcast at sun-set to the north-west, with lightning.
2	*Thurso* . . .	15th „ „ 8 P. M.	$8\frac{1}{3}$° N. $84\frac{1}{4}$° E.	Dull and cloudy to north-west, and much thunder and lightning.

No.	Ship.	Date.	Position.	Chararcter of squall.
3	*Kerbela* . . .	17th April 1883. 8 P.M.	Gopalpore	Wind strong from north-west, (Force 7) squally, with thunder, lightning, and rain.
3	*Chilka* . . .	17th April 1883.	Ditto .	Strong squall from north-west working round to south, with heavy rain. thunder and lightning. (Force of wind 7)
4	Diary of Mr. S. R. Elson	27th „ „ . 10 to 11-30 P.M.	Saugor . .	The first cold blast of a north-east squall struck us. Wind in gusts from force 5 to 7. The wind kept persistently in the north-east till 11-30, when the rain ceased.
5	Ditto . . .	29th April 1883, 8 to 10 P.M.	Sandheads .	Was struck by the first blast of a well-formed and wildish looking arch of a north-wester from due north, with rain and lightning. It lasted for 2 or 3 hours, the wind hauling to north-north-west after it had blown for some time.
6	*Maharatta* . .	21st May 1883 .	Chittagong River	Heavy squall from the north-west for two hours.
7	*Star of Denmark* .	24th „ „ . 7 to 8 P.M.	20° N. 87° E. .	North-west squall, which lasted one hour.
8	*Coconada* . .	18th April 1884. 8 P.M.	Chittagong River	Squall, with heavy rain and heavy gusts of wind.
9	*Booldana* . .	23rd April 1884	Off Pooree .	Very heavy south-south-west squall.
10	*Ellora* . . .	21st „ „ .	Off coast between Coconada and Madras.	The weather was squally, with much lightning to the north and west, with violent squalls, thunder and lightning.
11	S. S. *Australia* .	1st May „ .	Proceeding up River Hooghly	Had heavy south-west squall, with vivid lightning and heavy rain, at 4 P.M.
12	S. S. *Edinburgh* .	2nd „ „ .	Near Upper Gaspar light-ship.	Had a light squall from north-north-west.
13	S. S. *Pemba* . .	4th „ 1885 .	19¼° N. 89½° E. .	Heavy squall of wind, with incessant and very vivid lightning and heavy rain.
14	S. S. *Tenasserim* .	4th „ 1886 .	16° N. 94° E. .	Heavy squall of wind and rain from north-west, and vivid lightning from south-west and to north during the squall.
15	Ditto . . .	5th „ „ .	19° N. 90½° E. .	Had a heavy squall of wind and rain from the north-west, which lasted 40 minutes.
16	S. S. *Rossshire* .	13th May „ .	19¼° N. 87½° E.	Had heavy squall of wind and rain, accompanied with thunder and lightning.
17	Diary of Mr. S. R. Elson.	1st „ 1883. Evening.	At anchor at Diamond Harbour.	A very hard blast struck the vessel, due to an arched squall from west to west-south-west. It blew very violently until the rain began. The ship *Blair Athol*, which was half-mile lower down the river, was blown clean around.

2nd.—Isolated squalls during the South-West monsoon.—Whenever a moist air-current is blowing, there is always a tendency to the formation and occurrence of rain-squalls. This tendency is apparently very much increased if the moist air-current meets with any sudden obstruction, or if it advances towards another air-current which differs much in temperature, humidity or other characteristic features. Hence, in front of the advancing south-west monsoon up the Bay in the months of May and June there are always frequent rain-squalls. These squalls appear to be very frequent in the neighbourhood of Ceylon just before the south-west monsoon current enters the Bay in May.

There is no doubt, notwithstanding the statements to the contrary made by such authorities as Maury, &c., that what is ordinarily called the south-west monsoon in India commences at the entrance of the Bay and works up the Bay. It marches up the Bay in a more or less rapid rush at a rate of sometimes as much as 200 to 300 miles a day. Before it advances over the centre of the Bay during the latter part of May or beginning of June, light variable winds usually prevail; whilst near the head of the Bay local south-west winds blow across the coast into Bengal. These local sea-winds commence in February or March, and extend slightly seawards in April, and blow very strongly in April and May. They are notwithstanding mere local land and sea winds or breezes, and such as are always felt more or less off the shore of a country with a dry and heated interior. The first advance of monsoon winds over the south and centre of the Bay apparently resembles to some extent the sudden advance of a rapidly moving fluid mass into an inert mass, and there is much irregular and whirling motion. This shows itself by the frequent occurrence of squalls. During the prevalence of the south-west monsoon the winds blow intermittently, that is, strongly for some days, and then fall off in strength. During these weak intervals the amount of rain in Northern India is comparatively small. These intervals of fine weather form what are called "breaks in the rains." During these breaks there is a tendency for the south-west monsoon to back down the head of the Bay. After some little time, and apparently under the increasing pressure of the winds in the south of the Bay, it advances again. Each advance is similar in character to the first great burst of the monsoon in May or June. It is a rush of strong winds over an area previously occupied by feeble winds, and is attended with more or less squally weather. Hence, squalls are of frequent occurrence over the Bay at the commencement of the monsoon, and over the north of the Bay during the whole monsoon period from May or June to October. As already pointed out, the air-current which gives rise to these squalls is a damp humid current, bringing up vast quantities of aqueous vapour, and hence having a vast store of energy. If this energy be released and set free rapidly, the squally weather, which indicates slight atmospheric disturbance, may gather strength and grow into a large cyclonic storm.

Examples of these squalls in the north of the Bay are given below, extracted from the logs of vessels sent in to the Meteorological Office.

The neighbourhood of the West Pegu and South Arakan Coast appear to be very liable to rain-squalls during the height of the monsoon. These are evidently due to the obstructive action of the Arakan hills, which are from

1,000 to 4,000 feet in height, and which divert the direction of the monsoon current from S. W. to S. and S. E.

The neighbourbood of the Madras Coast also appears to be subject to these squalls during the south-west monsoon months, July to September. The south-west monsoon winds which blow across the Bombay Coast are forced up across the Western Ghâts, during which they give up a considerable portion of their moisture, and thence proceed across the Deccan as comparatively dry winds. The wind directions of the Deccan stations indicate that the current advances eastward across the Peninsula, and nearly at right angles to the current up the Bay of Bengal. Its velocity is considerable, nearly as great as that of the Bay of Bengal current. Much irregular motion and action occur near the meeting ground of these two aerial currents, just as is the case where two large rivers meet when, as is well known, there is much irregular and whirling motion, accompanied by up-rushes and down-rushes of small portions of the water. Hence, during the rains proper, rain-squalls are of occasional occurrence along and near the west coast of the Bay. This action is, as might be expected, most frequent near the head of the Bay. This interference of the Bombay branch of the monsoon current undoubtedly gives rise to frequent squalls in that part of the Bay, and it is probably in part due to this that small cyclonic storms occur so frequently during the months June to September.

The following are examples of isolated squalls in different parts of the Bay of Bengal during the south-west monsoon which were not a part of any cyclonic storm. It will be seen that the large majority of these occurred off the Ceylon and Coromandel Coasts, and in the north-west of the Bay. The number of examples of squalls off the Arakan Coast is very limited, but this is mainly due to the limited data:—

Examples of isolated squalls in the Bay during the months June to September.

No.	Ship.	Date.	Position.	Character of squall.
1	*Laomene* . .	18th June 1887 .	2° N. 77° E. .	Heavy rain squall from north-west.
2	*Ailsa* . . .	30th Sept. 1883 .	2½° N. 88½° E.	Lightning and heavy squalls from north-west.
3	*Earl of Shaftesbury* .	30th June 1886 .	4° N. 76° E. .	Smart squall; wind and rain from west-north-west.
4	*Tibre* . . .	18th Sept. 1883 .	6° N. 80° E .	Very violent squalls and continual rain from north-west and west-north-west.
5	*Thessalus* . .	30th „ „ .	6° N. 87° E. .	Hard squalls from north-west.
6	*Secundra* . .	5th June 1887 .	Penang . .	Heavy squall with rain from north-west.
7	*Queen of Scots* .	28th Aug. „ .	6½° N. 82° E. .	Heavy squall from north-west with rain and lightning.
8	*Tibre* . . .	29th July 1883 .	8° N. 81¼° E. .	Very violent squalls from west and north-west.
9	*E. L. Capitan* . .	13th July 1888 .	10½° N 86¾ E. .	Heavy squalls of wind with torrents of rain and lightning in north-west.
10	*Governor* . .	29th June 1887 .	12° N. 84° E. .	Hard squalls from west-north-west to south-west.
11	*Bancoora* . .	23rd „ „ .	12° N. 84° E. .	Strong squall from north-north-west and heavy rain.

No.	Ship.	Date.	Position.	Character of squall.
12	*Laomene* . .	24th June 1887 .	12° N. 85° E. .	Heavy rain squalls and fresh wind squalls from west-north-west to west.
13	*Pelican* . . .	18th June 1885 .	Madras Harbour	Hard squall lasting about half-an-hour with heavy rain.
14	*City of Calcutta* .	12th July 1888 .	13½° N. 85° E. .	Squalls with heavy rain and much lightning in north-west.
15	*Jason* . . .	30th June 1886 .	13° N. .	Very strong squall from north-west, with great quantities of rain.
16	*Westergate* . .	1st Sept. 1883 .	14° N. 84° E. .	Hard north-west squall, with thunder, lightning and much rain.
17	*Tibre* . . .	20th July " .	15° N. 82° E. .	Violent squalls from west and north-west.
18	*Sahara* . . .	27th Sept. 1888 .	15° N. 85½° E. .	Very heavy rain squalls from north-north-west.
19	*British Duke* . .	8th July " .	15½° N. 85½° E.	Very hard squalls from west north-west.
20	*Nepaul* . . .	14th Sept. 1886 .	15¾° N. 83½° E.	Completely overcast, sudden shift of wind, to north-west, wind reaching force 8 in puffs, thunder and lightning, lasted half an hour; rain few drops.
21	*Ganges* . . .	22nd July 1886 .	15¾° N. 84½° E.	A violent squall from north-west, with thunder, lightning and heavy rain.
22	*City of Khios* . .	2nd July 1888 .	15¾° N. 85½° E.	North-west squall, with very heavy rain.
23	*Maharaja* . .	7th " " .	15¾° N. 95¾° E.	Heavy squalls from north-west, with rain.
24	*Clan Drummond* .	9th June 1887 .	16° N. 83° E. .	North-west squall, rain and vivid lightning.
25	*Blythswood* . .	8th July 1885 .	16½° N. 86¾° E.	Overcast and cloudy; sea slightly increased, lightning in the north-west and one or two claps of thunder ending with a heavy squall from north-west by west.
26	*Jason* . . .	3rd July 1886 .	Pt. Pagoda in sight.	Squally from westerly direction.
27	*Patna* . . .	6th June 1887 .	Bimlipatam .	A north-west squall of no great violence, rainy, wind variable.
28	*Clive* . . .	11th July " .	18½° N. 91° E. .	Heavy squalls from north-west with rain.
29	*Tibre* . . .	1st Sept. 1883 .	19° N. 86° E. .	Rain squalls from north-west.
30	*Cleomene* . .	12th " " .	19° N. 88½° E. .	Smart rain squalls from north-west.
31	*Euphrates* . .	14th Aug. 1888 .	Kyaukphu .	Very hard squalls of wind and rain from north-west to north with much lightning and thunder.
32	*E. L. Capitan* . .	9th Aug. 1887 .	20° N. 87° E. .	Squalls of wind and rain from north-west.
33	*Tenasserim* . .	8th July 1886 .	20° N. 89° E. .	Heavy squall of wind and rain from north-west; wind increasing till noon when strong westerly squall.
34	*Enterprise* . .	28th June 1888 .	20¾° N. 89½° E.	Heavy squall from north-west, with heavy rain, thunder and lightning.

The whole of the information up to the present date contained in the Meteorological Office records shows that isolated squalls during the south-west monsoon proper occur chiefly in the following four portions of the Bay, arranged in order of frequency :—

1st.—The area between Lat. 12° N. and 16° N. and Long. 83° E. and 86° E. (more especially in June and July).

2nd.—The north-west angle of the Bay.

3rd.—The neighbourhood of the Ceylon coast.

4th.—The neighbourhood of the South Arakan and West Pegu coasts.

3rd.—**Squalls during cyclonic storms.**—These have already been fully described in page 89, and it is hence not necessary to repeat these remarks. Examples will be found in the history of the six cyclones, Chapter III.

An interesting point in connection with the occurrence of squalls in cyclonic storms and cyclones is their distribution with respect to the different quadrants of the storm. It is a point on which it is not easy to obtain very satisfactory information. An examination of the records in the Meteorological Office of the weather in the Bay of Bengal during the six years 1882-87 gives the data tabulated below.

The cyclonic area is divided into four quadrants, *viz.* north-east, south-east, south-west and north-west, and the number of different occasions on which severe to intense squalls were observed in each of these quadrants during cyclonic storms or cyclones in the period 1882-87 is given in the columns of the following table :—

	Number of occasions on which severe to intense squalls were noted by different vessels in cyclonic storms.				
	N.-E. Quadrant.	S.-E. Quadrant.	S.-W. Quadrant.	N.-W. Quadrant.	Total.
Months of May, June, July, August and September	9	19	18	3	49
Months of October and November . .	18	13	12	14	57

The results are very interesting, and, although not pretending to exactness, probably give a rough approximation to the law of distribution. They show first that in the storms of the rains heavy squalls are far more frequent in the south-east and south-west quadrants than in the north-east and north-west quadrants, and that they are of rare occurrence in the north-west quadrant.

In the cyclones of October and November they occur with nearly the same frequency in all quadrants, but with a slight tendency to greater frequency in the north-east than in the other three quadrants. The table also indicates that severe to hurricane squalls occur more frequently during the two-monthly period of October and November than during the five-monthly period extending from May to September; it is thus a striking proof of the frequent great intensity of the October and November cyclones that velocities of 50 and 60 miles are probably well within the mark. I have however not been able to

ascertain whether any accurate measurements have ever been made of the rate of motion of the cyclonic swell in the Bay of Bengal.

The direction of swell produced by storm.—This important subject in connection with cyclones was first fully discussed by Colonel Reid, in Chapter III of his work "On the progress of the development of the Laws of Storms and of Variable Winds" published in 1849. The explanation given in that chapter is, on the whole, adequate and satisfactory, and is adopted with some slight modification in the following paragraphs.

The power of the wind blowing steadily for some time over the surface of a sheet of water in producing ripples and waves is well known. When the winds are strong and approach in force to a gale, and blow over an extensive ocean-surface, waves of 30 to 40 feet in height, and separated by intervals of 200 to 500 feet are the not infrequent result. Measurements have been made by many observers which shew that these figures are fair estimates of such waves. It appears at first sight anomalous that the apparent effect of a strong and steady wind rubbing against the water-surface should be to give rise to these vast pulsations, oscillations, or waves. The action of the wind is doubtless more or less irregular, and the waves are in part, if not entirely, due to the accumulated effect of these irregular actions, just as the sound of a violin string, produced by an apparently regular movement of the bow, is in reality due to a rapid succession of brief pulls and slips of the bow on the string.

Whatever explanation be adopted of the production of these large waves, there is no doubt of the general principle that air moving over a water-surface always produces waves, and that the magnitude of the waves is dependent upon the extent of water-area over which they blow and upon the force of the winds. There are several principles in connection with wave-movement which are deserving of notice in connection with the present subject.

As already stated, the rapid movement of air over the surface of the sea gives rise, by some species of cumulative action, to a continuous succession of large parallel waves so long as the winds are fairly steady in character. Waves that are produced in this manner travel steadily onwards in the same general direction so long as they meet with no obstruction, and if they pass beyond the area of strong winds decrease slowly in height and force. It occasionally happens that two or more sets of waves due to different actions and travelling in different directions over the same sea-area meet and, as it were, pass through each other. In this case the result in the meeting-ground is a confused motion usually described as a cross-sea, and sometimes as a confused sea. This effect is developed to the greatest extent in and near the central or calm area of large cyclones, where the resultant action of the wave-motions transmitted in all directions is to give a peculiar up-and-down movement usually described as a pyramidal sea, in which all appearance of onward wave-movement

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(which is one of the most striking properties of waves) has apparently disappeared. The following is a graphic description of such a sea extracted from the log of a vessel which went through the centre of a storm in the Bay of Bengal. "Wind north-east. Tremendous squalls, blowing with inconceivable fury; the sea rising in huge pyramids, yet having no velocity, but rising and falling like a boiling cauldron. I have never seen the like before. I was in the height of the terrible hurricane of September 1834 in the West Indies. I have been in a typhoon in the Chinese Sea, in gales off Cape Horn, and the Cape of Good Hope, but never saw such a confused and strange sea. I have seen much higher seas and heavier wind, but then the sea was regular and the wind steadier."

The effect of the squalls and other actions in cyclones in giving rise to a peculiarly heavy and confused sea is well described in the previous extract. The height or force of the sea due to a cyclonic storm in fact apparently bears no direct and simple relation to the general strength of the cyclone. For example, the Madras pier was breached in May 1881, during a storm of moderate severity, accompanied however by a peculiarly dangerous and violent sea. Again, Calcutta pilots described the sea they experienced in the False Point cyclone of September 1885, and the Balasore cyclone of May 1887, as exceedingly violent and dangerous, and almost appalling in appearance, even to men accustomed to the heavy seas of the south-west monsoon at the head of the Bay.

The waves, when originally produced by the action of the moving air on the surface of the sea, move at a rate which is mainly dependent upon the velocity of the wind, and are hence called forced waves, because their rate of motion is determined by the body or action which produces them, *viz.* in this case the moving air. Waves, when produced by such an action, do not cease when the action stops, or when they pass in their motion beyond the sphere of action of the producing winds. In such cases they pass onwards in the same general direction as before, but gradually become smaller and smaller until at last they become imperceptible. In this case, as soon as they pass beyond the influence of the strong winds which produced them, they become what are termed free waves—waves which are propagated onwards in virtue of properties of the fluid itself and independent of any other cause. In this case the rate of motion depends upon the depth and other properties of the water. One observer many years ago measured waves up to 36 feet in height with crests 340 feet apart as a maximum and running up to 32 miles per hour. Theory seems to indicate that the swell in the outskirts of a cyclonic storm probably travels even more rapidly. If such waves meet with an obstacle, they tend to pass round it, and are more or less deflected according to circumstances.

In the case of cyclonic storms the winds blow from different directions in different quadrants. In the northern quadrants, in which easterly winds prevail, the air-motion will produce waves moving in a westerly direction. These

waves, when once fully produced, will tend to move in the same direction, and will not be dragged round the centre except perhaps to a very small extent, and will hence change their direction of motion as they pass onwards either not at all or very slightly. Such waves once produced will hence tend to pass away from the storm area, thrown off as it were like mud from a carriage wheel, and will continue to advance in the same general westerly direction for considerable distances over the open sea, gradually and slowly decaying; and if they meet a coast, will give rise to a heavy swell from the eastward, which will evidently increase in strength if the storm approaches that coast.

Similarly, waves or swell from the north-east will be transmitted by the action of the winds in the north-west quadrant.

The following diagram illustrates according to Colonel Reid's explanation the production of an easterly or east-south-easterly swell on the Madras Coast, and of a north-east swell at Trincomalee or on the north-east coast of Ceylon, in the case when a storm, which has formed near the Nicobars, is advancing westwards to the Madras Coast:—

Example of Swell raised by a Storm.

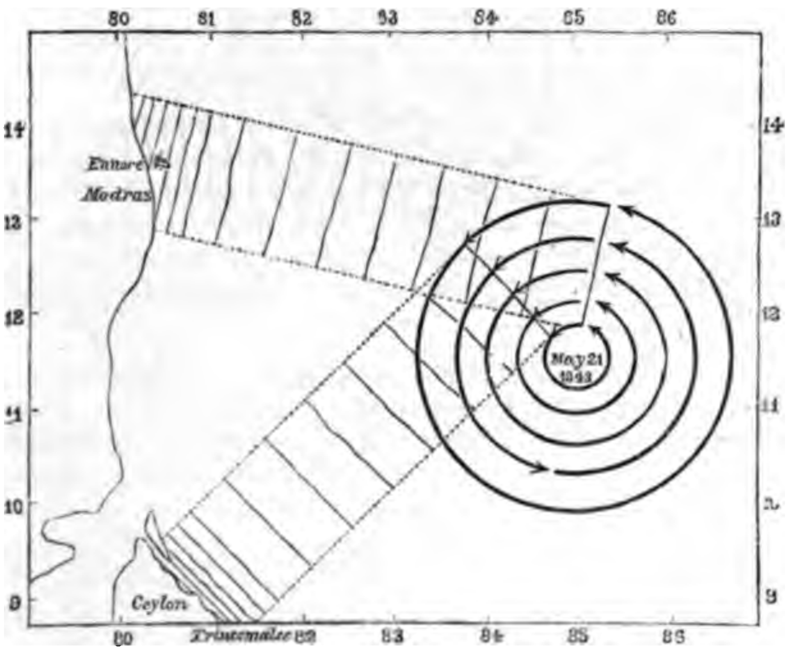

FIG. 17.

It is also evident from the preceding explanation that waves will tend to pass out from each portion of a cyclonic storm, and give rise to swell passing out from the central storm area in all directions. The following diagram also, taken

from Colonel Reid's book, illustrates this power of the winds of a cyclonic storm to give rise to swell passing outwards in all directions from the storm area:—

Cross Sea and Swell raised by a Storm North of the Equator.

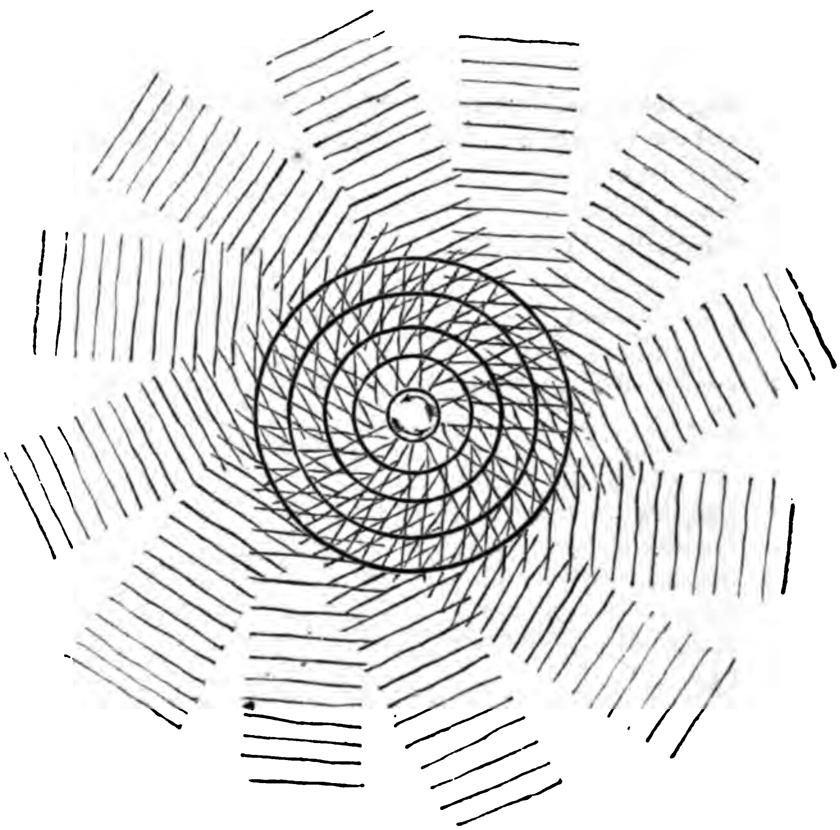

Fig. 18.

We have hence the following inferences from the previous discussions:—

1st.—If a cyclonic storm has formed in the Bay of Bengal, it is a kind of centre from which waves or swell tend to pass out in all directions, and the direction from which the swell is experienced on any part of the coast of the Bay outside the storm area nearly coincides with the direction or bearing of the

storm centre. Numerous examples establishing or confirming this are given below.

2nd.—Again, it is evident that the strength of the swell or the distance at which it will be sensibly felt in the open sea, will depend partly upon the strength of the producing winds, and partly upon the distance over which the producing winds act with no considerable change of direction. The former, of course, depends upon the intensity of the winds and hence upon the intensity of the cyclone, and the latter almost entirely upon its extent. Thus the severe easterly winds of a small but intense cyclone may give rise to a heavy swell at the same distance from the centre as the moderate strong easterly winds of a much larger but shallower depression. Hence, with a certain amount of experience, the strength of the swell due to a distant cyclone may not only serve as a rough guide to its bearing, but also to its character (*i.e.* its size and intensity).

A very important point in connection with this is the distance from the storm centre at which the swell can be felt. In the Bay of Bengal the data given below shew that it has been distinctly felt when the storm centre was at least 400 miles distant in space, and 48 hours distant in time. In these extreme cases it was approaching the coast where the swell was observed.

The following interesting extract from Colonel Reid's work already referred to proves that it is felt at even greater distances in the Atlantic:—

"I was in Bermuda when the hurricane of 1839 occurred, and distinctly heard the sea breaking loudly against the south shores on the morning of the 9th September, full three days before the storm reached the island, as recorded in tables of the state of the weather kept at the Central Signal Station. At that time the hurricane was still within the tropics and distant ten degrees of latitude. As the storm approached, the swell increased, breaking against the southern shores with louder roar and great grandeur until the evening of the 12th September, when the whirlwind storm reaching the Bermudas set in there. When the storm had passed over the Bermudas, the southern shore became calm, and the northern reefs, in their turn, presented a white line of surge caused by the undulations rolled back from the storm in its progress towards Nova Scotia and Newfoundland."

The following gives extracts from the logs of vessels of the swell experienced by them during recent cyclonic storms in the Bay, together with data shewing their distance from the storm centre, and the bearing of the storm centre for comparison with the direction of the swell. It will be seen that they confirm almost without exception the conclusions stated above:—

Swell.

Number.	Ship.	Position.		Bearing of the centre.	Swell.		Wind.	Reference.
		Latitude.	Longitude.		Direction.	Character.		
1	*Gilcruix*	19° 49N	86° 42E	468 miles S 57°E.	South-east	Heavy	East	Balasore cyclone, page 10.

Swell—concluded.

Number.	Ship.	Position.		Bearing of the centre.	Swell		Wind.	Reference.
		Latitude.	Longitude.		Direction.	Character.		
3	*Asia* .	17° 19′ N.	85° 7′ E.	453 miles S 84°E.	South-west	Heavy .	Variable	Balasore cyclone, page 12.
4	*Cousins Arbib.*	20° 2	86° 35	358 miles S 59°E.	East .	Do. .	N. E. to E.	Do., page 15.
5	*Sirsa* .	18° 4	87° 41	168 miles N 80°E.	East-north-east.	Heavy confused	N. W..	Do., page 19.
6	*Cocanada*.	20° 28	92° 57	220 miles S 53°W.	East .	Confused	S. E. .	Do.
7	*Chyebassa*	22° 33	88° 31	286 miles S 23°E.	East .	Do. .	N. N. E.	Do.
8	*Kalima* .	11° 00	85° 50	304 miles N 64°E.	North-west	Heavy .	S. to N. W.	Akyab cyclone, page 15.
10	*Comet* .	20° 46	87° 40	534 miles S 17°E.	South-east	Heavy cross.	S. .	Do., page 16.
11	*Comet* .	20° 46	87° 40	386 miles S 31°E.	South-east .	Heavy cross.	N. E. .	Do., page 18.
13	*Sirdhana*.	16° 35	86° 37	377 miles N 65°E	North-east.	Heavy .	W. .	Do., page 22.
14	*City of Khios.*	20° 40	88° 05	266 miles S 66°E.	Easterly .	Do. .	N. N. W.	Do.
15	*Comet* .	20° 46	87° 40	296 miles S 66°E.	South-east	Heavy cross.	N. E. .	Do.
16	*Star* .	21° 00	88° 12	266 miles S 60°E.	South-east	Heavy .	N. .	Do.
17	*Meteor* .	21° 02	88° 46	238 miles S 56°E.	South-west	Do. .	N. .	Do.
18	*Satara* .	19° 47	89° 12	679 miles S 40°W.	Southerly .	Considerable.	S. E. .	Madras cyclone, Appendix, page 60.
19	*Satara* .	17° 22	90° 54	453 miles S 61°W.	South-south west.	Heavy .	S. S. W.	Madras cyclone, Appendix, page 61.
21	*QuangTung*	19° 53	89° 11	158 miles S 12°E.	South-easterly.	Do. .	E. by S.	Do., page 95.

It will now be seen that the subject has a most important practical bearing It has been shewn that the waves produced by the strong winds of a cyclonic storm pass outwards beyond the storm area, and produce a very observable swell at distances of 400 and 500 miles away from the centre. The swell advances across the Bay with an average velocity probably considerably exceeding 25 miles per hour, or much greater than that at which the storm advances. And hence frequently the first sensible indication of a distant but approaching cyclonic storm is the increasing swell which may be felt from one to three days before the arrival of a storm, and the way in which it increases in force affords to those who have some acquaintance with the character of the swell, sea, &c., on that part of the coast, a fair estimate of the extent or intensity of the approaching cyclone.

It is a very simple indication, but it is, I believe, a very valuable one, and it is much to be wished that greater use was made of it, and that fuller data were forthcoming in order to test the conclusions of the present chapter and also, if found possible, to make them more definite and precise.

Set at the Head of the Bay.—One important indication at the head of the Bay (and more especially at the Sandheads), of unsettled weather in the centre or north of the Bay is the set or current which commences almost with the disturbance and increases with it. In consequence of the peculiar shape of the Bay (converging and contracting northwards), and of the shallowness of the water over a considerable area near the head of the Bay, and of the large quantities of fresh water brought down by the Ganges and Megna, the currents at and near the head of the Bay are always considerable, but in ordinary weather shift with the tides. The strong southerly winds which prevail for some time before a whirl has been definitely formed, and also during its existence, appear to give, in the south and centre of the Bay, by surface friction, a general north-easterly impetus to the water, which, north of Diamond Island, is converted into a coast current that is deflected near the head of the Bay, and gives rise to a steady set or drift to the west. If a cyclonic storm has formed in the centre or north of the Bay and moves in a west or north-west direction to the Orissa or Bengal Coast, the rotatory air-motion sets up a similar, but of course much feebler, rotatory motion of the water-surface in the centre and north of the Bay, and hence also gives a westerly motion to the water at the head of the Bay. Consequently, the westerly increasing set of the water at the head of the Bay is a marked and characteristic feature of the antecedent weather which favours cyclone formation, as well as of the cyclone itself. It is probable that the strength of a cyclone advancing to the north-west coast of the Bay could be roughly ascertained by the strength of the westerly set at the head of the Bay. Data are however wanting to test this. Innumerable examples of the westerly drift of current might be given from recent information sent in by ships. A few will suffice.

The log of the P. V. *Coleroon* for the 14th June 1886 (just before she experienced the cyclone of June 12th to 16th) remarks: "There was a strong westward set during the day." The *City of Bombay*, which was approaching the mouth of the Hooghly on the morning of the 15th, had a strong west-north-west current The log of the *Scottish Chieftain*, in lat. 20° 50′ N. and long. 88° 10′ E. on the 28th June, during another small storm of the rains, remarks that she had a very strong westerly current, and on the 30th June when in lat. 20° 32′ N. and long. 87° 34′ E. states: "We still experience a very strong westerly set." The *Moulmein*, in the storm of 21st September 1878, experienced at the head of the Bay a strong current setting westerly about 2½ knots per hour.

Currents in cyclonic storms in the Bay of Bengal.—In the preceding paragraphs it has been briefly explained how the cyclonic winds, by friction with the surface-water, &c., may give rise to strong urrents in the Bay of Bengal. Near the coasts the directions of the currents are largely modified. In the open sea the currents over the whole storm area of fierce and hurricane winds approximately agree in direction with the winds, and are probably stronger than are generally imagined. The drift near the centre of a large storm in the Bay of

Bengal may be as much as 6 to 8 knots or miles per hour, and mariners should be prepared for a drift of this magnitude in the larger cyclonic storms in the Bay.

The following are a few of the more remarkable instances of strong currents during cyclonic storms in the Bay during the last few years, and shew that the estimate given above is probably not too large:—

Ship.	Date.	Position.	Direction and amount of Current.
S. Ballarat . .	9th November 1886.	$10\frac{3}{4}^\circ$ N. $81\frac{3}{4}^\circ$ E.	Current during 72 hours S. 8° E. 150 miles.
Airlie . . .	21st November 1886.	15° N. $92\frac{3}{4}^\circ$ E. .	The ship was found to be 130 miles to north-west by west of her position by dead reckoning after allowing 4 knots for dead drift during the cyclone. (The last preceding observation was taken 48 hours before.)
Argo . . .	28th November 1886.	Madras Roads .	Extraordinary strong north current near Madras—4 to 5 knots.
Satara . . .	14th November 1883.	$16\frac{3}{4}^\circ$ N 94° E. .	A current set the ship from noon of 11th instant to noon of 14th instant N. 13° W. 171 miles.
Satara . . .	15th November 1883.	16° N. $95\frac{3}{4}^\circ$ E. .	Current during the previous 24 hours W. 65 miles.
Bancoora . .	30th June 1883.	20° N. $88\frac{1}{3}$ E. .	Current 80 miles adverse.
Moulmein . .	21st September 1878.	On voyage from Calcutta to Chittagong.	Experienced a strong current setting westerly about $2\frac{1}{2}$ knots per hour.
Akbar . . .	6th November 1886.	$9\frac{1}{2}^\circ$ N. 90° E.	She was in the outer gale circle of cyclone, and yet the current which she experienced during the previous 24 hours had carried her (if her log may be trusted) 160 miles to the N. 70° E. or at a rate of between 6 and 7 miles per hour.
Ireshope . . .	16th October 1874.	$20\frac{1}{2}^\circ$ N. $88\frac{1}{2}^\circ$ E.	A strong current setting to south-west 5 miles per hour.
Belfast of Liverpool .	8th October 1882	$20\frac{1}{2}^\circ$ N. $87\frac{1}{2}^\circ$ E.	Strong south-westerly current running against which the ship could make no progress.
Do. .	9th October 1882	$20\frac{1}{2}^\circ$ N. $87\frac{1}{4}^\circ$ E.	Found current running between south-south-west round to north-west from $1\frac{1}{2}$ knots to 3 knots per hour.
Do. .	10th October 1882.	$20\frac{1}{4}^\circ$ N. $87\frac{1}{4}^\circ$ E.	Current running very strongly to the south-west.
Do. .	11th October 1882	$20\frac{1}{4}^\circ$ N. $87\frac{1}{4}^\circ$ E. .	Strong south south-west current changing to south-west, west-south-west and north-west.
Nith . . .	8th October 1882	$20\frac{1}{2}^\circ$ N. $87\frac{3}{4}^\circ$ E.	South-west to west-south-west current, 35 miles.
Do. . . .	11th October 1882.	20° N. $87\frac{3}{4}^\circ$ E. .	Very strong south-west current.
Do. . . .	14th October 1882.	20° N. $89\frac{1}{2}^\circ$ E. .	Current west-south-west, 48 miles.
P. V. *Coleroon* .	22nd September 1885.	Sandheads near the mouth of the Hooghly.	During day and preceding night there was some 4 to 5 knots set to westward.

Hence it may be assumed that the currents may vary from 2 to 3 knots in the outer storm area to 6 to 8 knots in the inner storm area, and that near the

head of the Bay the currents may even be greater than this. If a mariner be caught in a cyclonic storm near the head of the Bay, he should, in shaping his action, take carefully into consideration the fact of the strength of the storm currents at the head of the Bay and in the inner storm area, and of their direction as determined by the position of the storm and the shape and conformation of the Bay.

Distribution of cyclones according to season.—The next important subject to be dealt with is the origin and line of march of cyclones in the Bay of Bengal as determined by the season.

In the first place theory suggests, and experience confirms, the principle that cyclonic storms do not form over or near the equator. Squally weather with strongish gusts of wind during the squalls is by no means unusual, but these squalls never form part of a cyclonic circulation or whirl. All experience shews that they are only breaks or interruptions of comparatively brief duration in the ordinary weather of the season, and that they do not form part of a large and rapid eddying motion of the air, such as constitutes a cyclone. There is no record during recent years of a storm having formed to the south of lat. 9° N., and it *may be accepted as a general principle that the lowest latitude in the Bay at which cyclonic storms are formed or met with is lat. 8° N.*

The continued accumulation of cyclone records shews that the one feature which appears to be absolutely essential to the formation of a large cyclonic whirl or revolving storm in the Bay is an inrush of moist southerly winds. Such inrushes take place occasionally before the permanent setting in of the south-west monsoon. Hence cyclonic storms may occur at any time during the period when the south-west monsoon current blows steadily, and also during the period in which brief advances of south-west winds may occur over the south or the whole of the Bay at the commencement of the south-west monsoon, and hence at any time during the period April to December. They are rare in the limiting months April and December. *Hence it may be assumed that storms may occur at any time during the period May to November, and under exceptional circumstances in April and December.*

Another equally important principle or generalization is, that all cyclones that occur in the Bay are generated in the Bay. There is not a single example on record of a cyclonic storm having formed in the Arabian Sea and passed across India into the Bay of Bengal. On the contrary; hardly a year passes which does not furnish an example of a storm which originates in the Bay of Bengal, passes across India and gives rise to stormy weather in the Arabian Sea for some days. The fierce storm of November 2nd to 15th, 1886, which originated near the Andamans and passed over Madras and advanced across the Peninsula and the Arabian Sea to the entrance of the Persian Gulf, may be cited as an example. The P. and O. Steamer *Peshawar* was involved in it in lat. 16½° N. and long. 60° E., and the S. S. *Mobile* (proceeding from Bushire to Bombay) in lat. 23½° N. and long. 62° E.

Hence all cyclonic storms in the Bay of Bengal originate or are produced in the Bay itself.*

* A storm which crossed the Bay on the 14th and 15th September, 1888, was probably an exception to this rule, as it apparently entered the Andaman Sea and the Bay of Bengal from Tenasserim and the Gulf of Siam.

The Bay of Bengal has thus the peculiar advantage of being a small isolated meteorological area. Its geographical position and features constitute it into a self-contained area in this respect. It is thus of special interest, as the process of storm generation, on either the large or small scale, may be observed in it from the very earliest stages. And with the growth of knowledge on the part of the Meteorological Department, and of skill on the part of the sailor, there is no reason why a ship, and still less a steamer, should ever be involved in the inner or dangerous portion of a severe cyclonic storm in the Bay.

During the past fifteen years (since the establishment of the India Meteorological Department in 1875), some 150 cyclones of all degrees of magnitude have been observed and recorded, from the intense Backergunj cyclone down to the feeble but frequent whirls of the months of July and August.

The chart (Plate XXVIII) gives the place of origin so far as is known of these cyclones. This chart will repay ample study. The condensation theory indicates that the conditions favouring the formation of a cyclone may occur in any part of the Bay during the whole period that the south-west monsoon current prevails in any portion of it. The chart confirms this inference most clearly. Hence it is well that the mariner should not accept unreservedly such statements as that cyclones originate only in certain portions of the Bay, as for instance, to the west of the Andamans, &c. He must in fact separate completely in his mind what is probable from what is possible.

Hence it may be laid down as a rule that cyclones or cyclonic storms can originate in, or advance over, any part of the Bay to the north of lat. 8° N. near the coast or in the centre of the Bay or the Gulf of Martaban during the months of April to December.

There is a belief that the area to the west of the Andamans possesses certain peculiarities which favour the origin of fierce cyclones. This opinion is so widely spread that it is in newspapers, &c., frequently referred to as the birthplace of cyclones in the Bay. The only special feature is that this area is near the centre of the sea or water surface comprising the Gulf of Martaban and the Bay of Bengal. Cyclones forming near the Andamans have hence a longer path before they reach land than if they originated nearer to the coast, and hence, if the conditions are favourable, are more likely to develop into large and dangerous cyclones. This appears to be the sole reason why the cyclones that form in that part of the Bay are larger and more intense than those formed near the head of the Bay, and are on the whole the most violent of all storms experienced in the Bay.

Experience shews that cyclonic storms and cyclones (more especially the latter) usually increase in intensity as they approach the coast, and that the lowest pressures are recorded in the calm centre shortly before reaching land. Hence the danger of being caught in a cyclone near the coast is increased by the exceptional strength of the storm when approaching it. The dangerous quadrant in cyclonic storms is the right advancing quadrant, and hence in the great majority of storms in the Bay of Bengal, it is the western or north-western quadrant.

The following paragraphs give a full statement of what is known of the distribution of cyclonic storms in the Bay of Bengal during the cyclone season, April to November, and is illustrated by storm track charts given at the end of

the book. The principles stated in the present section are of much importance. A brief inspection of the storm track charts at the end of the volume (Plates XVII to XXVI) will shew that the storms of the Bay of Bengal are much more regular in their occurrence and track than might at first sight be supposed. It is very desirable that the sailor in the Bay of Bengal should recognize these general laws of distribution of cyclonic storms in that area, as each inference, statement or law represents a large amount of accumulated experience, and tells him when and where he may expect to meet storms in the Bay, and also the chance of their occurrence and character at any given time. Thus, by an inspection of the charts, the reader can ascertain for any month—

1st.—In what part of the Bay he is likely to meet with a cyclonic storm, and in what part cyclonic storms rarely or never occur at that time.

2nd.—What is the usual track or tracks of cyclonic storms which form or appear during the month in the Bay.

Another important point, but which cannot be ascertained directly from these charts, is what are the chances or probability that a storm forming in any month will be of moderate or great intensity (that is, whether it will be a cyclonic storm or a cyclone).

In the event of encountering squally weather in the outskirts of a cyclonic storm, the reader will, by means of this information, be enabled to decide independently of wind indications the probable position and track of the storm he may encounter in the Bay so far as it depends upon the time of year. If the wind indications confirm this, he will at once recognize that the storm is of the character and kind normal to the season. If it occurs in a different portion of the Bay or is moving in a different manner than is usual, he will be at once prepared for the fact that the storm is of a different character from those normal to the season, and will in such a case make even more exact and careful estimate of its position and track, and take greater precautions than he would do in the first case. The chances of a storm being normal in character appear to be about ten to one. Hence these laws about to be stated are, like many of the laws, &c., upon which man is compelled to act, mere summaries of past experience which afford a probable and useful, but not a certain and infallible guide for action.

The sailor, like the meteorologist, must hence carefully remember that, although the weather conditions which give rise to storms are fairly regular in character, and subject to laws which are now known more or less exactly, it is possible that very exceptional conditions may occur at distant intervals and give rise to storms of exceptional and abnormal intensity, course, &c.

The storm track charts given in Plates XVII to XXVI, at the end of the book, consist of two series. The first series (Plates XVII to XXIV) give the track of all cyclonic storms which have formed during the eleven years 1877—87 in the Bay of Bengal, and have had an existence on land of at least 24 hours after crossing the coast. The tracks of the storms of the first five years of this period are filled in chiefly from the land observations, as meteorological data from ships in the Bay were not available in the majority of cases. Hence the tracks of these storms in the Bay are to some extent doubtful. They may, however, be accepted as approximately correct.

The second series of charts (Plates XXV and XXVI) are based on the information which has been systematically collected from vessels entering the port of Calcutta during the six years 1882—87, and shew the tracks of all storms during that period in which winds of force 8 and upwards were actually experienced by vessels. It is to be regretted that it is not possible to give these tracks for more than six years at present, as that is almost certainly not a long enough period to furnish an approximate estimate, month by month, of the laws of occurrence and distribution of what may be termed dangerous storms, or storms in which winds of excessive violence prevail.

The first series of charts are given rather for the information of those who study storms, with a view to endeavour to ascertain their causes, &c., than for sailors who are chiefly anxious to utilize any aids they can have to avoid these storms which may involve them in stormy weather and dangerous winds.

The following are the more important facts with respect to storm occurrence and distribution in the Bay of Bengal, derived in part from an examination of these charts, and in part from the lists of storms given in the "weather charts of the Bay of Bengal, and adjacent seas north of the Equator," compiled by Mr. Dallas, First Assistant Meteorological Reporter to the Government of India.

April.—It has already been pointed out that cyclonic storms never occur in the Bay unless humid south-west winds (*i.e.* the winds of the south-west monsoon) are blowing over the south of the Bay at least. These winds do not set in permanently until the middle or end of May, but previously to that date, south-west winds occasionally advance northwards for a brief period across the entrance of the Bay as far north as the Tenasserim coast and the south or centre of the Bay and then retreat again. These occasional bursts of south-west winds may occur at any time during the month of April, but are most probable in the latter part of the month. Sometimes these advances, if unusually powerful, give rise to cyclonic storms. No information has been received in the Meteorological Office of the occurrence of any cyclonic storm in this month during the past eleven years. This however only proves that they are comparatively rare. The storms of the first fortnight of May, which form under similar conditions, (*i.e.* during partial or irregular advances of the south-west winds over the south of the Bay) almost invariably originate to the west or west-north-west of the Nicobars, and advance in a west-north-west direction to the Madras coast. The following list of all known or recorded storms in the Bay in the month of April shews that the same rule is true for the month of April :—

13th April 1749.—A furious hurricane on the Coromandel Coast.

27th April to 1st May 1840.—A cyclone crossed from the Andamans to the Orissa coast; the centre passed just south of Pooree.

23rd April 1848.—Violent hurricane off Ceylon.

23rd to 28th April 1850.—A cyclone was formed to the west of the Nicobars and passed northwards to Bengal.

21st to 23rd April 1854.—Violent hurricane in the Gulf of Martaban.

9th and 10th April 1858.—Cyclone passed from the Andamans to Cape Negrais, and thence into Lower Burma.

21st to 27th April 1859.—Gale over the Bay of Bengal and Andaman Sea. It was most violent in the neighbourhood of Negapatam.

6th to 11th April 1860.—Cyclone formed over the centre of Bay to the westward of the Nicobar Islands.

22nd April 1875.—Cyclone off the Coromandel Coast.

Of these nine cyclonic storms, four travelled westwards to the Ceylon or Coromandel Coast, two formed in the Andaman Sea and advanced northwards into Lower Burma. The remaining three marched in a north-north-west direction to the Bengal Coast. The two last storms were of exceptional character and intensity.

Hence cyclonic storms are of comparatively rare occurrence in the Bay of Bengal in April. They form either in the south of the Bay or in the Andaman Sea. Those which form in the Bay proper are generated to the west of the Nicobars or Andamans, and march (in at least three cases out of four) in a west or west-north-west direction to the Ceylon or Coromandel Coast. Those which originate in the Andaman Sea march northward to the Lower Pegu Coast. Storms are somewhat less probable in this month in the Andaman Sea than in the Bay of Bengal.

May.—This month not only witnesses occasional irruptions of south-west humid winds over the south of the Bay, but also in normal years the permanent advance of the great monsoon current into the Bay which usually occurs in the third or fourth week of the month. Hence cyclonic storms are a characteristic feature of the weather of the month, and are occasionally of exceptional strength and violence. If they form in the first fortnight, they are almost invariably due to a temporary advance of these winds, and hence originate in the south of the Bay or the AndamanSea. In the former case they march in a west-north-west direction to the Coromandel Coast. If they are generated during the great advance of the monsoon current in the latter half of the month, they generally form in the centre of the Bay, and advance in some northerly direction towards the coast of Arakan, Bengal or Orissa. The following gives a list of the cyclonic storms whose tracks are given in the track chart of the month (Plate XVII) :—

May.

Year.	Date.	Course in Bay.	Coast crossed by centre.	Character.
1877	12th to 22nd May .	W.-N.-W. to N.-N.-W.	Coromandel Coast .	Severe cyclonic storm.
1879	19th to 24th „ .	W.	Coromandel Coast to the north of Madras.	Ditto ditto.
1879	29th to 2nd June .	W.-N.-W.	Balasore Coast . .	Feeble.
1881	26th to 28th May .	N.-N.-W.	Bengal Coast near Saugor Island.	Ditto.
1884	13th to 17th „ . .	N. to N.-E.	Arakan Coast . .	Intense ditto.
1886	22nd to 24th „ . .	W.-N.-W.	Coromandel Coast near Negapatam.	Feeble.
1887	21st to 28th „ . .	W.-N.-W. & N.-W.	Orissa Coast near Balasore.	Intense ditto.

Seven cyclonic storms occurred in this month during the 11 years 1877—87. Four of them were storms of great intensity and accompanied with hurricane

winds. Three advanced in a west-north-west direction to the Coromandel Coast, and the remaining four in a northerly direction to the Arakan or Bengal Coast at the head of the Bay.

Hence it is practically an even chance that if a cyclonic storm forms in the Bay in this month, it will be of great intensity (or a cyclone). If it forms during the first fortnight, the chances are about four to one that it will advance in a west-north-west direction to the Coromandel Coast, but if it forms during the last fortnight the probabilities are nearly two to one it will march in a northerly direction to the head of the Bay.

The following is a list of all storms in this month recorded previously to the year 1877:—

19th to 20th May, 1787.—Great storm at Coringa.

3rd May, 1811.—Great storm at Madras, which destroyed nearly every vessel in the roads.

8th May, 1820.—Cyclone at Madras, which crossed the Peninsula.

26th May, 1823.—Gale passed from the north of Bay over Balasore.

7th to 10th May, 1827.—Gale at Madras.

26th May, 1830.—Cyclone passed northward up the Bay into Bengal.

21st May, 1832.—Storm in Gangetic Delta.

21st May, 1833.—Storm at the mouth of Hooghly.

May 1840.—Hurricane off Madras and Southern coast.

16th May, 1841.—Cyclone passed from south-west of the Andamans to Madras.

31st May to 5th June, 1842.—Great cyclone in Calcutta on 3rd June—the most severe gale ever felt in Calcutta; centre passed over the city.

19th to 23rd May, 1843.—Cyclone passed from south of the Bay northward to Ongole.

11th May, 1844.—Gale at Noakhally and Chittagong.

12th and 13th May, 1849.—Gale at Chittagong.

30th April to 6th May, 1851.—Cyclone passed from the north-east of Ceylon to Madras; passed to the northward of the town.

12th to 15th May, 1852.—Cyclone started in latitude 15° and marched due north to the Sunderbans; the centre passing 39 miles east of Calcutta.

15th to 29th May, 1855.—Cyclone over the centre of Bay.

15th to 20th May, 1858.—Gale formed over the centre of Bay, and passed across the Coromandel Coast.

1st May, 1869.—Cyclone in the north-east of the Bay.

13th to 17th May, 1869.—Cyclone passed from Cape Negrais north-westward to Bengal.

28th to 30th May, 1870.—Cyclone in the north-east of the Bay.

1st to 3rd May, 1872.—Severe cyclone formed in about latitude 7° 30′ N. and passed north-westward to Madras.

28th to 31st May, 1872.—Slight gale in the centre of the Bay.

1st to 5th May, 1874.—Cyclone originated near latitude 9° N, longitude 85° E; travelled north-westward towards Madras, but did not reach land.

10th to 13th May, 1876.—Cyclone formed to west of 10° channel; travelled slowly northward.

This list gives 25 storms: 15 of these formed during the first fortnight of the month, of which 10 marched in a westerly direction to the Madras Coast Seven certainly formed during the last fortnight, of which at least five advanced in a northerly direction to the head of the Bay. The tracks of three of the storms are not sufficiently indicated to allow them to be classified. It will thus be seen that these facts agree very closely with those given in the preceding paragraph.

The preceding data establish that cyclonic storms are of comparatively frequent occurrence in the Bay during May (about two every three years). If they originate in the first fortnight of the month the chances are about three to one they will march in a westerly direction to the Coromandel Coast; but if during the latter half of the month the chances are four or five to one they will march northwards to the head of the Bay. It is also about an even chance that a storm forming in this month will be of great intensity (i.e. a cyclone).

June.—The south-west monsoon is usually established early in the month over the whole of the Bay. This fact at once suggests that the cyclonic storms of the month in the Bay probably form near the head of the Bay. A reference to the track chart of the month (Plate XVIII) shews that 14 storms occurred in this month during the period 1877—87. All of these storms formed to the north of latitude 18° N., and the great majority of them to the north of latitude 20° N. Five out of these storms advanced in a northerly direction into Bengal or Behar across the Bengal or North Orissa Coast. The remaining nine marched in a westerly direction across the Orissa Coast into the Central Provinces, or in a west-north-west direction into Upper India (*i.e.* the Punjab and North-Western Provinces). One of these storms advanced across the whole length of the Peninsula, and passed out into the Arabian Sea. The following gives the list of these fourteen storms:—

June.

Year.	Date.	Course in Bay.	Coast crossed.	Character of Storm.
1880	1st to 4th June .	N.-N.-W.	Bengal Coast near Saugor Island.	Feeble cyclonic storm.
1880	25th to 30th „ .	W. to N.-W.	Orissa near Pooree .	Ditto ditto.
1881	1st to 5th „ .	N.	Bengal (Sunderbuns) .	Ditto ditto.
1881	5th to 9th „ .	W.	Orissa Coast . .	Ditto ditto.
1881	13th to 19th „ .	N.-W.	Balasore Coast . .	Ditto ditto.
1883	14th to 19th „ .	N.-N.-W.	Balasore Coast . .	Moderate ditto.
1883	25th June to 4th July .	N.-W. & W.-N.-W.	Orissa Coast . .	Severe ditto.
1884	18th to 24th June .	W.	Ditto . .	Feeble ditto.
1884	28th June to 6th July .	N.-W.	Ditto . .	Ditto ditto.
1885	16th to 25th June .	N.	Bengal Coast . .	Severe ditto.
1885	25th to 29th „ .	N.-W.	Balasore Coast . .	Feeble ditto.
1886	14th to 22nd „ .	N. to N.-W.	Bengal Coast near Saugor Island.	Severe ditto.
1887	11th to 15th „ .	W.	Ganjam Coast . .	Moderate ditto.
1887	19th to 21st „ .	N.	Bengal Coast near Saugor Island.	Feeble ditto.

Hence the experience of the eleven years 1877—87 shews that cyclonic storms in June form almost invariably in the north of the Bay to the north of latitude 18° N, and generally to the north of latitude 20°N. and that the chances are almost even that they will advance in a northerly direction to the Bengal Coast or in a westerly direction to the Orissa Coast.

The following is a list and brief statement of the storms of the month in years previous to 1877 of which there are brief records :—

June, 1822.—Storm swept over Burrisal, travelling very slowly.

2nd June, 1823.—Storm at Chittagong and in the Delta of Ganges.

8th June 1824.—Heavy storm at Chittagong.

3rd to 5th June, 1839.—Storm traversed the head of the Bay from south-east to north-west.

18th to 30th June, 1857.—Cyclone formed over centre of Bay; apparently travelled north-westward towards Orissa.

12th to 17th June, 1859.—Gale off Akyab.

16th to 26th June, 1863.—Cyclone formed near Acheen Head.

5th to 10th June, 1869.—Cyclone generated over the north of Bay, which passed over Bengal.

28th June, 1872.—Small storm generated over the north of Bay, which passed over Balasore.

10th to 13th June, 1873.—Small storm formed off the Coromandel Coast, apparently travelled northwards.

15th to 17th June, 1874.—Small cyclone in the north-west of the Bay.

Of the eleven storms given in the preceding list, five advanced northwards into Bengal and four in a north-west or west direction across the Orissa Coast. The remaining two were very exceptional in character. None of these storms was of excessive violence. They were all in fact cyclonic storms of somewhat greater intensity than usual, or striking examples of the class of storms which are now known to be of comparatively frequent occurrence at the head of the Bay in June. The law of distribution, as indicated by this list, is practically identical with that of the previous list of storms in June 1877—87. Hence we have the following rule :—

Cyclonic storms are of frequent occurrence in the north of the Bay in June. They usually form to the north of latitude 20° N, or quite at the head of the Bay. One or two such storms may be expected every year. It is an even chance whether a cyclonic storm which has formed in the Bay in June will pass in some northerly direction into Bengal or in some westerly direction across Orissa. The chief feature of the June cyclonic storms is the strong westerly or south-westerly winds or gales in their southern quadrants. It should also be noted that two out of three advance across the north-west angle of the Bay immediately to the south of the entrance to the Hooghly, and hence, if severe, they are very trying to shipping leaving the Hooghly at such times.

July.—During this month the two monsoon currents, the Bengal and Bombay currents, blow most steadily and strongly. Cyclonic storms are of frequent occurrence in the Bay, but are generally of feeble strength. The storm track chart of the month (Plate XIX) shews that they almost without exception

originate to the north of latitude 19° N. and march in a west-north-west course across the Orissa Coast. The tracks of 21 storms which occurred during this month in the period 1877—87 are given in the chart. Of these eleven were feeble storms in which the force of wind did not exceed 7. Seven were moderate storms, in which winds of forces 8 and 9 were experienced, and three were severe and attended with hurricane winds (force 11 or 12). A brief statement of these 21 storms is given in the following table :—

July.

Year.	Date.	Course in Bay.	Coast crossed.	Character of Storm.
1877	11th to 15th July . .	W.	Balasore Coast . .	Feeble small cyclonic storm.
1878	20th to 30th „ . .	W.-N.-W.	Ganjam Coast . .	Moderate cyclonic storm.
1880	14th to 17th „ . .	W. & W.-N.-W	Balasore Coast . .	Feeble cyclonic storm.
1881	2nd to 4th „ . .	W.	Ditto . .	Ditto ditto.
1881	12th to 18th „ . .	W. & W.-N.-W.	Bengal Coast near Saugor Island .	Moderate ditto.
1882	11th to 16th „ . .	W.-N.-W.	Orissa Coast . .	Severe cyclonic storm.
1882	17th to 23rd „ . .	N.-W.	Bengal Coast near Saugor Island.	Ditto ditto.
1882	23rd to 26th „ . .	N.-W.	Balasore Coast . .	Feeble cyclonic storm.
1882	31st July to 2nd August	W.-N.-W.	Orissa Coast near False Point.	Ditto ditto.
1883	3rd to 5th July . .	N.-N.-W.	Coast of Sunderbuns in Bengal.	Moderate storm.
1883	6th to 10th „ . .	W.-N.-W.	Orissa Coast . .	Severe cyclonic storm.
1883	12th to 14th „ . .	W.	Ditto . .	Moderate.
1883	26th to 28th „ . .	W.-N.-W.	Bengal Coast near Saugor Island.	Ditto.
1884	9th to 14th „ . .	W.-N.-W. & W.	Orissa Coast . .	Ditto.
1884	15th to 18th „ . .	W.-N.-W.	Ditto . .	Feeble.
1884	18th to 28th „ . .	N.-W.	Ditto . .	Ditto.
1885	14th to 17th „ . .	W.-N.-W.	Orissa Coast near False Point.	Ditto.
1885	23rd to 25th „ . .	N.-W.	Balasore Coast . .	Ditto.
1886	16th to 23rd „ . .	W.-N.-W.	Ditto . .	Ditto.
1887	1st to 10th „ . .	N.-N.-W. & N.-W.	Orissa Coast . .	Ditto.
1887	17th to 27th „ . .	N.-N.-W. & N.-W.	Ditto . .	Moderate.

Storms exactly similar in character to the above occasionally originate in Bengal itself, generally in East Bengal. As they form under like conditions, they march in the same general westerly direction across the head of the Peninsula. The tracks of two of these storms are given in the storm-track chart of the month in illustration of this fact. The chief feature in these land-formed storms, as in the corresponding sea-formed storms, is the strong westerly and south-westerly winds which prevail in their southern and eastern quadrants.

The chart shews that 20 out of the 21 storms which formed in the Bay during this month in the period 1877—87 marched in a west or west-north-west

direction across the north-west angle of the Bay and the Orissa Coast, and in the great majority of cases they afterwards advanced across the head of the Peninsula into Sind, Guzerat or Rajputana. Out of the 16 storms which occurred during the period 1882—87 (*vide* Plate XXV), winds of force 8 or upwards were actually experienced in only 6 cases.

Hence, so far as these facts indicate, in July storms only occur in the north of the Bay. They are of comparatively frequent occurrence, an average of two or three occurring in every year. They usually march in a west or north-north-west direction across the north-west angle of the Bay to the Orissa Coast. The chances of a storm forming at this time marching in this direction are at least 10 to 1. They are frequently feeble, but in about one case out of three they give rise to strong westerly and south-westerly gales at the head of the Bay, in which the force of the winds exceeds 8. As they almost invariably cross the north-west angle of the Bay, and hence advance across the track of vessels leaving the Hooghly, outward bound vessels should not leave the river Hooghly when the storm signals are hoisted, unless fully prepared to encounter a severe storm of this kind, and should remain in the river until the lowering of the signals has indicated that the storm has passed landwards.

The following gives a complete list of cyclonic storms recorded in this month previous to the year 1877 :—

15th July, 1848.—Gale at the Sandheads.

23rd to 26th July, 1858.—Slight gale at the head of the Bay.

11th to 28th July, 1859.—Cyclone formed to west of Nicobars; travelled north-westwards.

25th to 31st July, 1860.—Gale off Ceylon and the Coromandel Coast.

16th to 18th July, 1871.—Gale in the Andaman Sea.

14th to 31st July, 1872.—Gale over the south of the Bay.

This includes only 6 storms extending over a period of nearly forty years. It thus confirms what has been stated on more than one occasion in this book, *viz.* that the July storms usually form close to the Bengal Coast, and in consequence give rise to westerly gales at the head of the Bay; the wind usually shifts slightly with the westward advance of the storms, but not sufficiently to indicate their cyclonic character, and the winds do not often rise in force beyond 8, and are very rarely, if ever, of hurricane strength (12).

It may be of interest to note that the average strength of the winds in this month in the Bay is 4·1, and that they are strongest in the mid-Bay between longitude 88° and 92° east, and latitude 12° and 16° north—where they average 5·3.

August.—The south-west monsoon blows somewhat less steadily in August than in July, although the mean force of the winds is the same (*viz.* 4·1). The winds are of greatest average force (5·4) in the area between 88° and 92° east meridians and 12° and 16° north parallels of latitude, or in the centre of the Bay. The track chart of the month (Plate XX) for the period 1877—87 gives the tracks of 18 storms. Fifteen of these originated in or to the north of latitude 20° north. Six advanced in a general northerly direction across the Bengal or North

Orissa Coast into Central and North Bengal. The remaining twelve (with one remarkable exception) advanced in a west or west-north-west direction across the coast of Orissa or Ganjam, and hence the great majority of these storms followed the usual track of cyclonic storms during the height of the south-west monsoon. They marched across the head of the Peninsula into Sind, Rajputana, or the western districts of the North-Western Provinces. The following gives a brief list of these 18 storms:*—

August.

Year.	Date.	Course in Bay.	Coast across which centre passed.	Character of storm.
1877	6th to 10th . .	N. . . .	South Bengal Coast . .	Feeble.
1877	13th to 17th . .	N.-N.-W. .	Ditto. . . .	Probably moderate.
1877	18th to 21st . .	N.-W. .	Ditto. . . .	Feeble.
1877	27th to 31st . .	W.-N.-W., & N.-W.	Balasore Coast . . .	Moderate.
1878	1st to 4th . .	W.-N.-W. .	Orissa Coast . . .	Feeble.
1878	6th to 8th . .	W.-N.-W. .	Balasore Coast . . .	Ditto.
1879	8th to 13th . .	W. & W.-N. W.	Ditto. . . .	Ditto.
1880	18th to 25th . .	N.-W. .	Ditto. . . .	Ditto.
1880	1st to 9th . .	W.-N.-W.	Ditto . . .	Ditto.
1881	1st to 4th . .	W. .	Orissa Coast near False Point	Ditto.
1881	16th to 19th . .	W.-N.-W.	Balasore Coast	Ditto.
1882	18th to 24th . .	W.-N.-W. .	Bengal Coast near Saugor Island.	Moderate.
1883	22nd to 26th . .	W. . .	Ganjam Coast . . .	Feeble.
1884	2nd to 9th . .	N.-N.-W. .	Balasore Coast . . .	Ditto.
1885	15th to 18th . .	W.-N.-W.	Ditto. . . .	Ditto.
1886	12th to 21th . .	N.-W. to N.	Orissa Coast near Pooree .	Moderate.
1887	17th to 20th . .	W. & N.-W	Ganjam Coast . . .	Feeble.
1887	21st to 25th . .	N.-N.-W. .	Balasore Coast . . .	Ditto.

The preceding data hence establish the following rule:—

Cyclonic storms are almost of as frequent occurrence in August as in July. Five out of every six form to the north of Lat. 20°. The chief feature of the storms of August as in July is strong westerly and south-westerly gales at the head of the Bay, and the shift of wind is rarely large enough to indicate their cyclonic character except in the north-west angle of the Bay. The storms of the month occasionally advance northwards across the Bengal Coast, but more frequently in a west or west-north-west direction across the Orissa or Ganjam Coast. The chances, based on previous experience, that a storm which forms in the month will advance in a westerly direction are two to one, and that it will advance north into Bengal are one to two. As the great majority of these storms advance across the track of vessels leaving the Hooghly, captains of vessels about to proceed to sea from Calcutta at a time when the storm

* The track of an additional storm which originated near Chittagong is given in the chart of the month. It is not included in the list, as it is not known whether it was land or sea-formed.

signals are hoisted, should, unless they are prepared to encounter strong winds and a very heavy sea, if possible remain in the river until the storm has advanced landwards.

The list of storms in August previous to the year 1877 recorded in the Meteorological Office is very imperfect for the reasons given for the similar deficiency in July, and is as follows:—

3rd August, 1834.—Gale at Calcutta.
21st August, 1844.—Cyclone at Calcutta.
9th to 17th August, 1857.—Gale over the northern half of the Bay.
18th to 19th August, 1857.—Gale over the centre of the Bay.
25th to 31st August, 1859.—Storm formed in about latitude 7° N., longitude 90° E., and travelled northwards to latitude 12° N.
17th to 21st August, 1861.—Slight gale over the head of the Bay.
9th to 12th August, 1862.—Gale over the centre of the Bay.
10th to 11th August, 1863.—Formed in the centre of the Bay to the westward of the Andamans.
28th to 31st August, 1863.—Gale in the extreme south of the Bay.
16th to 25th August, 1865.—Gale over the northern part of the Bay.
3rd to 6th August, 1873.—Storm formed over the centre of the Bay and travelled north-north-west.
1st August, 1874.—Cyclone crossed the north of the Bay from near Akyab and travelled west-north-westward.

This list confirms the preceding statement as to the general fact that storms are almost exclusively confined in this month to the north of the Bay. As a portion of the information is indefinite, it is not desirable to utilize it to modify the rule of probable occurrence of storms in August given above.

September.—The south-west monsoon blows less strongly and steadily over the Bay than in the preceding three months. It usually retreats from the greater part of Upper India (including the Punjab, Rajputana, Central India and the North-West Provinces) during the third or fourth week of the month. Hence it does not extend, on the average, so far northwards as in the preceding months of July and August. A reference to the storm track chart of the month (Plate XXI) will shew a similar feature in the storms of the month. They form further south in the Bay, and when they advance in a westerly track they cross the coast further to the south than storms usually do in July or August. The storm track chart of the month for the period 1877—87 gives the tracks of 19 storms, or an average of very nearly two for each year. Three formed to the south of latitude 16° north, and to the north-west of the Andamans. The remaining 16 originated to the north of latitude 17°, and of these the majority formed to the south of latitude 20°. Four of the 19 storms advanced in a general northerly direction into Bengal or Behar. The remaining 15 crossed the coast between Balasore and Masulipatam, and advanced in a general westerly direction across the head of the Peninsula. Their directions shew greater irregularity than those of the storms of July and August, although they are as persistent and long-lived.

The following is a brief statement of the storms whose tracks are given in the chart :—

September.

YEAR.	Date.	Course in Bay.	Coast across which centre passed.	Character of storm.
1877	5th to 11th Sept. .	W.-N.-W, & N.-W.	Balasore Coast . .	Moderate.
1878	13th to 21st „ .	W. & W.-N.-W.	Orissa Coast near False Point.	Feeble.
1878	18th to 24th „ .	N. & N.-N.-W.	Coast of Sunderbuns .	Moderate.
1879	12th to 17th „ .	W.	Orissa Coast near False Point.	Feeble.
1879	21st to 28th „ .	W. & W.-N.-W.	Orissa Coast near Pooree	Ditto.
1880	12th to 19th „ .	W. & W.-N.-W.	Ganjam Coast . .	Moderate.
1880	21st to 26th „ .	W.-N.-W.	Balasore Coast . .	Feeble.
1881	10th to 14th „ .	W.-N.-W.	Orissa Coast near False Point.	Ditto.
1882	6th to 15th „ .	W. & W.-N.-W.	South Orissa Coast .	Very severe.
1882	13th to 16th „ .	W.-N.-W. & N.-W.	Orissa Coast near False Point.	Moderate.
1882	26th Sep. to 3rd Oct. .	N.-W.	Ditto . .	Ditto.
1884	7th to 11th Sept .	W. & W.-N.-W.	Ditto . .	Feeble.
1884	16th Sep. to 1st Oct. .	W. and W.-N.-W.	Ganjam Coast . .	Probably moderate.
1885	15th to 17th Sept. .	W.	Balasore Coast . .	Feeble.
1885	19th to 25th „ .	N.-W.	Orissa Coast at False Point.	Intense cyclone.
1886	18th to 24th „ .	W.-N.-W.	Balasore Coast . .	Feeble cyclonic storm.
1886	28th Sep. to 3rd Oct. .	N.-W. to W.	Circars . .	Feeble.
1887	9th to 14th Sept. .	W.	Orissa Coast . .	Ditto.
1887	21st to 26th „ .	N. & N-N.-E.	Coast of Sunderbuns .	Severe cyclonic storm.

As might be expected from the general similarity of the weather conditions in the Bay and Indian area in September with those prevailing in July and August, the list of recorded cyclones previous to 1876 is as brief as the corresponding lists for July and August. The following comprises all the known storms of September previous to 1877 :—

5th and 6th September, 1808.—Cyclone at Vizagapatam.

19th to 21st September, 1839.—Cyclone passed northwards across Sunderbuns between Calcutta and Burrisal.

21st September, 1846.—Gale at Calcutta.

30th September, 1867.—Cyclone at Vizagapatam.

11th September, 1872.—Small cyclone in north-east of the Bay.

19th and 20th September, 1872.—Small storm in the north of the Bay.

This list includes six storms, of which two passed across the Bengal Coast and two across the Coast of the Circars. The path of the remaining two is not stated. Three of these storms are described as cyclones, and two of these three occurred during the last fortnight of the month.

The following gives a summary of these facts:

Cyclonic storms are as frequent in the Bay during September as in July and August, an average of two occurring every year. These cyclonic storms however, as a rule, form further south than in the previous two months, but usually to the north of latitude 17°N. The chances are four to one that the centre of a storm which forms in September will advance in a westerly direction to the north-west coast between Balasore and Coconada. About one storm out of five advances in a northerly direction into Bengal. The great majority of these storms are of small intensity and resemble the storms of July and August in general character, and in the strength of the westerly and south-westerly winds (as compared with the north-easterly and northerly winds) in the south and east quadrants. Under exceptional conditions, the chief of which appears to be the earlier retreat of the south-west monsoon than usual from Northern India, these storms are of great intensity and violence, and accompanied with hurricane winds. Hence cyclones are of occasional occurrence in September (and are most probable in the last fortnight). They form in the centre of the Bay, and the chances are about even that when such a storm has formed in the Bay in September, it will advance in a north-west direction to the Bengal Coast or in a westerly direction to the Coast of the Circars.

October.—The south-west monsoon begins to retreat down the Bay in this month. It also, in normal years, during the second or third week of the month, recurves in the centre of the Bay through south, south-east and east, and arrives on the Coromandel Coast as a north-east current giving north-east winds and frequent showers to the Coromandel Coast districts. The reversion of the south-west monsoon current, and the consequent commencement of heavy rain with strong north-east winds in Madras, are usually regarded as the setting in of the north-east monsoon on the Coromandel Coast. Hence, after this change occurs, north-east winds prevail more or less generally in the north and west of the Bay, and south-west winds in the south of the Bay. Between these areas there is an intermediate belt in which the winds are more or less variable and unsteady. In the district of predominant north-east winds the average wind force is 2·1, in the area of variable winds it is 2·8, and in the area of south-west winds it is 3·0. It will thus be seen that the conditions in the Bay during the month are very different from those of the preceding three months, and that the prevailing wind directions shew a general tendency towards cyclonic motion about an area in the centre of the Bay to the west of the Andamans.

In consequence of this disposition of winds, there is a marked tendency for cyclonic storms to form in the centre of the Bay farthest from land. There is hence a strong tendency for storms which form at this time to increase and become dangerous and extensive cyclones before they reach land. The storm track chart of the month (Plate XXII) illustrates the effect of the change of the weather conditions from September to October on the storm tracks in the most complete manner. The tracks of 13 storms which occurred during the month in the period 1877—87 are given. They originated in every part of the Bay south of lat. 20° N. (excepting the Andaman Sea), and their paths are as varied as their place of formation. The largest proportion, *i.e.* 6 out of 13, advanced in a westerly to north-westerly direction from the centre of the Bay to the Coast

of the Circars between Vizagapatam and Coconada. Five marched in a general northerly direction to the Coast of Bengal and Orissa. The remaining two marched from the south-west of the Bay to the Coromandel Coast.

The following gives the chief facts of these 13 storms:—

October.

Year.	Date.	Course in Bay.	Coast across which centre passed.	Character of storm.
1878 . .	13th to 16th October.	N.-N.-W.	Coast of Circars .	Moderate cyclonic storm.
1878 . .	28th to 31st October.	W.-N.-W.	Ditto .	Ditto.
1879 . .	10th to 15th October.	W.-N.-W. & N.-W.	Balasore Coast .	Ditto.
1879 . .	25th to 27th October.	N.-N.-W. & N.	Bengal Coast near Chittagong.	Feeble cyclonic storm.
1880 . .	12th to 15th October.	W. & W.-N.-W.	Coast of Circars near Vizagapatam.	Moderate cyclonic storm.
1881 . .	2nd to 9th October.	N.-W.	Coast of Circars north of Vizagapatam.	Ditto.
1882 . .	12th to 18th October.	N.& N.-N.-E.	Orissa Coast .	Severe cyclonic storm.
1882 . .	26th October to 2nd November.	N.-W.	Coast of Circars east of Coconada.	Moderate cyclonic storm.
1884 . .	15th to 18th October.	W.	Coromandel Coast near Negapatam.	Severe cyclonic storm.
1884 . .	24th to 26th October.	N. & N.-E.	Bengal Coast .	Ditto.
1884 . .	29th October to 2nd November.	N. & N.-N.-E.	Coast near Saugor Island and Chittagong.	Intense cyclonic storm.
1886 . .	16th to 20th October.	W. & W.-N.-W.	Coast of Circars north of Coconada.	Small cyclone.
1887 . .	8th to 14th October.	W. & W.-N.-W.	Coromandel Coast near Madras.	Moderate cyclonic storm.

It will thus be seen that the distribution of storms in the month of October is very irregular, and it is for this reason, as well as on account of the occasional great intensity of the storms, that October is on the whole the most dangerous and treacherous month of the year in the Bay.

The following gives a list of all the recorded cyclones and cyclonic storms previous to 1877:—

7th October, 1737.—A violent earthquake and furious hurricane occurred at the mouth of the Ganges.

2nd October, 1747.—Hurricane in Madras roads; storm not felt at Pondicherry.

31st October, 1752.—Violent hurricane, Madras Coast; rain fell continuously for several days.

21st October, 1763.—Severe gale at Madras; all vessels in the roads lost

29th October, 1768.—Severe gale at Madras; not felt at Pondicherry.

20th October, 1782.—Gale at Madras.

26th to 27th October, 1792.—Gale at Madras.

19th October, 1800.—Furious hurricane at Ongole and Masulipatam.

28th October, 1800.—Hurricane at Coringa and Masulipatam.

23rd to 24th October, 1818.—Cyclone at Madras; centre passed over town.

31st October, 1831.—Cyclone at Balasore and Cuttack.

30th October, 1836.—Cyclone at Madras; centre passed over town.

19th October, 1838.—Gale at Keejiri near the mouth of the Hooghly.

2nd to 5th October, 1842.—Cyclone passed across the north of Bay in a north-west direction, striking the coast near Cuttack.

22nd October, 1842.—Cyclone started from the Andamans, passing westward to Pondicherry.

12th to 14th October, 1848.—Cyclone generated in the north of the Bay; travelled north-westward to False Point.

20th to 23rd October, 1851.—Cyclone formed over the north of the Bay; centre passed over False Point light-house.

6th October, 1854.—Hurricane to south-east of Ceylon.

2nd to 5th October, 1864.—Tremendous cyclone; travelled from north-west of the Andamans to Bengal.

25th October, 1864.—Cyclone in the north of the Bay; passed over Vizagapatam.

27th October, 1867.—Cyclone travelled from the Nicobars to Bengal; passed over Port Canning.

7th to 8th October, 1869.—Storm travelled from the north-east of the Bay to the mouth of the Hughli.

24th to 26th October, 1872.—Cyclone in the Andaman Sea; passed over Narcondam Island.

13th to 16th October, 1874.—Cyclone of great violence, originated in latitude 16° N, longitude 89° E, passed north-westwards to the mouth of the Hooghly and over Midnapore.

24th to 26th October, 1874.—Cyclone passed over Coconada.

5th October, 1876.—Severe cyclone formed to the west of the Andamans, and travelled west-north-west to Vizagapatam.

29th October, 1876.—Cyclone of exceptional violence formed near the Andamans, which travelled by a curved track to the mouth of the Megna, where the storm wave drowned 100,000 people.

This list includes 27 storms. Eleven marched in a northerly direction to the Bengal and Orissa Coasts, five to the Coast of the Circars, and ten to the Madras or Coromandel Coast. One only formed in the Andaman Sea, *viz.* the storm which marched over the Island of Narcondam. All these storms were, with perhaps the exception of two or three of these which crossed the Madras Coast, cyclones, and several were of very great extent and of exceptional severity and intensity.

The following is a summary of the above facts:—

Cyclonic storms occur less frequently in the Bay in October than during any of the four preceding months. They are of very rare occurrence in the

Andaman Sea, and rarely, if ever, form to the north of lat. 20° N. in the Bay of Bengal. They may originate in any other part of the Bay, but form most frequently in the centre of the Bay between the Andamans and the Coast of the Circars. If a storm forms in this month, the chances are probably about one to two that it will develop into a severe cyclone. The chances are about even that a storm generated in this month will advance westwards to the Coast of the Circars, and if it does so, the chances are also about even that it is a feeble or a severe storm, or in other words a cyclonic storm or a cyclone. The chances are about one to three that if a storm forms in this month it will advance northwards to Bengal or Orissa, and if it does, the chances that it will be a severe storm or a cyclone are at least two to one. The chances that if a storm forms it will advance to the Madras Coast are also about one to three, but if it does, the chances that it will be a severe storm are probably about even.

November.—The general conditions in the Bay during this month are on the whole similar to those of the preceding month. The south-west monsoon winds retreat and cover a smaller area in the south and centre of the Bay than in October. The monsoon current recurves as in October, and continues to advance as a current giving north-east damp winds and much rain to the Coromandel Coast districts. North-east winds extend over the whole of the north of the Bay and are of average force 3·4, whilst the mean strength of the south-west winds in the south of the Bay is barely 3·0. The average strength of the winds in the intermediate belt of variable winds is practically the same as that of the south-west winds. Hence the conditions of the month indicate that storms will occur similar in character to those of the month of October, but that they will probably form less frequently, and on the average further to the south, than in the preceding month.

A reference to the storm track chart of the month (Plate XXIII) will shew that these inferences are fully borne out by facts. The following gives a list and brief statement of the 15 storms of the month which occurred during the period 1877—87 :*—

November.

Year.	Date.	Course in Bay.	Coast across which centre passed.	Character of storm.
1877	2nd to 5th November	N.-N.-E. & N.	Arakan Coast . .	Small cyclonic storm.
1878	3rd to 6th „	N.-N.-W. & N.-W.	Coast of Circars . .	Moderate cyclonic storm.
1879	1st to 5th „	N. & N. N.-W.	Coast of Lower Burmah	Severe cyclonic storm or cyclone.
1879	15th to 20th „	W.-N.-W. & N.-W.	Coast between Madras and Masulipatam.	Ditto.
1880	19th to 22nd „	W.-N.-W.	Coast near Negapatam	Small, but severe cyclone.
1881	10th to 13th „	N.-N.-W. & N.-W.	Coromandel Coast near Madras.	Severe cyclonic storm or cyclone.
1882	21st to 26th „	W. & W.-N.-W.	Coromandel Coast between Negapatam and Madras.	Very severe cyclonic storm or cyclone.

* One of the storms whose track is given in the chart of the month broke up on approaching the Coromandel Coast, and is hence not included in this list.

November—continued.

YEAR.	Date.	Course in Bay.	Coast across which centre passed.	Character of storm.
1882	28th to 30th November	W.-N.-W.	Coromandel Coast near Madras.	Moderate cyclonic storm.
1883	9th to 14th "	N.-W. to N.-E.	Arakan Coast . .	Cyclone small, but severe.
1883	28th November to 7th December.	W.-N.-W. to N.-E.	Chittagong Coast .	Severe cyclonic storm or cyclone.
1884	19th to 21st November	W.-N.-W.	Coromandel Coast near Madras.	Moderate cyclone.
1885	2nd to 3rd "	W. & W.-N.-W.	Coast north of Madras	Moderate cyclonic storm.
1885	17th to 23rd "	N.-N.-E. & N.-E.	Chittagong Coast .	Very severe cyclonic storm or cyclone.
1886	2nd to 6th "	N.-W. to W.	Madras Coast . .	Large and severe cyclone.
1886	14th to 24th "	N.-W. to W.	Coast of Circars .	Ditto.

It will be seen that, with one exception only, all these storms formed to the south of latitude 16° N., and that twelve formed in or to the south of latitude 12° N. Three originated in the Andaman Sea, but of these three two passed out into the Bay of Bengal. Four of the storms advanced to the north-east coast of the Bay between Akyab and Chittagong; two to the coast of the Circars, and the remainder (with the exception of one, which passed from the Andaman Sea into Burmah) to the Coromandel Coast between Nellore and Negapatam. Of the 15 storms, ten were cyclones, and the remaining five were cyclonic storms of moderate intensity.

The following gives the list of recorded storms of the month of November previous to 1877:—

November, 1797.—Gale in the north of the Bay.

12th to 17th November, 1839.—Cyclone passed across the Bay from the Andamans to Coringa.

21st November, 1840.—Gale to the north-east of the Andamans.

28th November, 1843.—Cyclone travelled from latitude 6° N, and longitude 90° E, in a north-westerly direction, but did not reach land.

9th to 14th November, 1844.—Cyclone to the east of the Andamans.

29th November to 2nd December, 1845.—Cyclone passed from the south of the Bay westward to Ceylon, centre passing near Batticaloa.

17th to 19th November, 1850.—Cyclone formed in the Andaman Sea, east of Port Blair, and travelled north-north-west.

17th to 21st November, 1856.—Cyclone formed in the centre of the Bay, and passed westwards towards Madras.

2nd November, 1857.—Cyclone formed to the east of Ceylon; centre passed over Nellore.

5th November, 1864.—Cyclone passed over Masulipatam.

12th November, 1867.—Cyclone in the north-east of the Bay.

November, 1868.—Cyclone at Akyab.

5th November, 1870.—Cyclone formed in the centre of Bay; passed to Vizagapatam, where the wind blew with hurricane force.

3rd November, 1873.—Severe cyclone, latitude 15° 30′ N., longitude 85° E.

1st November, 1874.—Cyclone passed over Coconada from east.

10th to 12th November, 1874.—Cyclone originated about latitude 19° N., longitude 84° E., and travelled northward; broke up between Pooree and False Point.

Hence cyclones may form in any part of the Bay and Andaman Sea to the south of latitude 16° N. in the month of November. Two out of three storms which originate in this month form in, or to the south of, latitude 12° N. At least one storm may be expected every year in this month. The chances that a storm in November will be a cyclone are about two to one. If a storm forms, the chances that it will advance to the Coromandel Coast are about 2 to 1. About one storm out of three that form advances to the coast of East Bengal or Arakan. The part of the Bay which is most free from cyclonic storms in this month is the north-west angle of the Bay and the coast from Saugor Island to Vizagapatam. On the other hand, the north-east coast of the Bay is more liable to cyclones in this month than in any other month of the year.

December.—The south-west monsoon generally covers only the more southerly portion of the Bay during the early part of December, and usually withdraws from it in the third week of the month. This retreat is due to increasing weakness in the current. Hence, although in the very limited extent over which it prevails, and in some other conditions it resembles the corresponding conditions of the month of May, the current or air motion in the south of the Bay in December is marked by great general feebleness, as compared with that of May, and hence differs entirely in the important feature of strength. Hence it is evident that storms will be of exceptional occurrence in the month of December, and that they will be confined almost entirely to the south of the Bay. The track chart of the month (Plate XXIV), it will be seen, fully confirms this inference. Only three storms occurred in December during the eleven years 1877—87. They all formed in the south of the Bay. Two of them crossed the Coromandel Coast, and the third the Coast of the Circars. They all marched in a west-north-west or north-west direction, and broke up shortly after reaching land and without crossing the Peninsula—

December.

Year.	Date.	Course in Bay.	Coast across which centre passed.	Character of storm.
1878	4th to 9th	W. & W.-N.-W.	Coast of Circars .	Severe cyclonic storm.
1884	12th to 19th	W.-N.-W.	Coast near Negapatam.	Ditto.
1886	7th to 9th	W.-N.-W.	Coromandel Coast near Madras.	Ditto.

The distribution of the storms of the month is much better shown by the list of recorded cyclonic storms in the Bay previous to 1877. The list is as follows:—

4th December, 1803.—Violent hurricane between Trincomalee and Madras.

10th and 11th December, 1807.—Gale at Madras. Storm local; not felt to the north of Pulicat, nor at Pondicherry.

2nd December, 1830.—A gale of the most violent description at Pondicherry and Cuddalore; at Madras slight gale felt in evening.

6th December, 1831.—Cyclone at Pondicherry and Cuddalore, lasting only a few hours, but fearfully destructive.

10th December, 1849.—Severe hurricane at Madras.

4th December, 1850.—Hurricane at Madras.

10th to 12th December, 1874.—Storm in the south of the Bay.

This, in addition to the three already mentioned, gives a total of ten storms during the present century. At least six of these storms were cyclones, that is, were accompanied with hurricane winds at and near the centre. Nine out of these ten storms advanced in a west-north-west direction to the Coromandel Coast, and nearly all struck the Coast between Madras and Negapatam. These statements hence indicate the following rule:—

Storms are of comparatively rare occurrence in the month of December, and no storm is known to have formed in the Bay during the present century after the 15th of the month.—No storm has been known to form in the Andaman Sea in this month. Storms occasionally form in the south or south-west of the Bay of Bengal between the Ceylon Coast and the Andamans. The chances are nearly two to one, that if a storm occur in this month it will be a violent cyclone. It is also almost a certainty that a storm which forms in this month will advance in a west-north-west direction to the Coromandel Coast between Madras and Negapatam. Hence they are chiefly dangerous in the area between the East Ceylon Coast and the Coromandel Coast.

Barometric Indications.—These have already been discussed from a general standpoint in the preceding chapter. All that is now necessary is to summarize the facts and principles so far as they bear directly on the determination of the existence and character of cyclonic storms.

The movement of the barometer in the Bay of Bengal is, in ordinary weather, very regular, and is confined within narrow limits. In fine weather the most noticeable and important change is the regular up and down movement (occurring twice a day) known as the diurnal oscillation or the daily barometric tides.

When a cyclonic storm or cyclone is forming or has formed and is advancing over the Bay, it is usually merely the inner part of an extensive area of barometric depression and of cyclonic circulation.

If the storm be a small one, or what is termed a cyclonic storm, the depression or fall of the barometer below its normal height for the period is never large. It increases in amount from the outskirts of the depression to the centre of the storm, but even there it does not exceed two or three-tenths of an inch in the great majority of the smaller cyclonic storms in the Bay.

If the storm be a fierce and extensive cyclone, it consists, as has been already pointed out, of—

1st.— An outer storm area.
2nd.—An inner storm area.
3rd. —A calm central area.

In the outer storm area the barometer does not fall more than four or five-tenths below the normal height of the season. The inner storm area is one of comparatively small diameter, in which the barometer falls with excessive rapidity until the calm centre is reached. The barometer, it is believed, stands at nearly the same height over the whole central calm area at the same instant, but varies with the changes in intensity of the storm. As it should be the object of the mariner to avoid the inner storm area, it is only necessary to give the barometric indications by which he can recognize that he is in an area of barometric depression, and approaching or entering a cyclonic storm, or is in the outer storm area of a cyclone.

If the mariner in the Bay of Bengal is provided with a proper barometer, and makes the daily comparison suggested and explained in pages 31 to 42, he can use the variations of the barometer from the normal as storm indications by means of the following rule :—

If the reduced barometer reading is at any time during the cyclone season, April to November, a tenth of an inch below that normal to the time, the probabilities are two to one that a cyclonic storm is formed in the Bay ; if ·15" below it the probabilities are at least three to one ; and if two-tenths of an inch below, it is practically certain that a cyclonic storm has formed.

In this manner, whilst he is quite in the outskirts of a cyclonic storm, his barometer may strengthen and confirm the inference derived from the appearance of the sky and weather, the occurrence of squalls, &c. of the formation or existence of a cyclonic storm in his neighbourhood.

Another rule or principle, but one less simple in its application than the previous, is the following :—

If the barometer at or near the same place (or if proper allowance be made for change of place) falls a tenth of an inch in 24 hours in any part of the Bay, the chances are about 2 to 1 that a storm is forming in the neighbourhood of the place, or is approaching the place ; if it falls 15" in 24 hours, the chances are about four to one that a cyclonic storm or cyclone is forming or approaching ; and if it falls two-tenths of an inch or upwards in 24 hours, it is almost practically certain a cyclonic storm is approaching the place.

Mariners should also remember that whilst a storm is forming, the barometer is frequently unusually high and steady beyond the outskirts of the cyclonic storm. The same conditions of a high and steady barometer also frequently obtain in very fine settled weather. It is partly on this account, and partly on account of the very small fall of the barometer in the outer portions of cyclonic storms in the Tropics that that instrument as ordinarily used by sailors frequently gives no indication to them of the approach of a storm until it is too late to be of any use.

Wind indications.—We have already in part discussed the important question of the bearing of the centre of a cyclonic storm with respect to the wind

direction (pages 20 to 23). We there considered the general relations holding between baric gradients and wind direction and force. We repeat the chief points of those remarks before taking up the special question of how to utilize the measurement of wind direction to ascertain the bearing and course of the centre of cyclonic storms.

One of the most important features of the weather is the occasional occurrence of what are called barometric depressions. These are really vast revolving eddies or whirls in the atmosphere. Just as an essential feature of an eddy in water is a difference of level at the upper surface of the water (greatest in the middle of the eddy), so in an atmospheric eddy there is at the bottom of the eddy or at the earth's surface a difference of pressure which is greatest in the middle or interior of the eddy. The pressure or height of the barometer decreases from the outskirts of the eddy towards the interior. It is perhaps difficult to grasp fully that in a large cyclonic storm a vast mass of air 200 or 300 miles in diameter and ½ mile to 2 or 3 miles in height, is whirling or circulating round in a somewhat complicated manner, which, at and near the earth's surface, has been described as spiral, or vorticose. All observations of cyclonic storms shew that such, however, is the case. Such an eddy is called a barometric depression from one feature, *viz.* that the barometer is depressed below its natural or normal height in the eddy at the earth's surface, and that the depression increases towards the centre in a fairly regular manner. It is also called a cyclonic circulation, cyclonic storm or cyclone, from the manner in which the air moves or whirls in a regular manner round a definite point or small area in the interior of the eddy or whirl. The point in such an eddy where the barometer stands lowest, and which, so far as experience shews, generally coincides with the point about which the air circulates and towards which it is drawn, is called the centre. The shape or form of these atmospheric eddies is best shewn by the lines of equal pressure or isobars indicating and defining cyclonic storms in weather charts. They are very rarely circular, and are usually more or less oval and fairly regular in shape. They differ very largely in size, and also in the rate at which the air moves. Hence a cyclonic circulation may be either feeble, moderate or violent. If feeble, it is of little or no importance to sailors, except so far as they choose to use the winds for progress. If moderate, it may be called a "cyclonic storm," and if very violent, a cyclone or hurricane.

As suggested by Mr. Blanford, it appears to be desirable to retain the use of the word 'cyclone' for the most violent storms in the Bay of Bengal, and to employ the term 'cyclonic storm' for the less violent disturbances which are of frequent occurrence during the whole of the south-west monsoon period.

In cyclones and cyclonic storms the pressure slope or baric gradients are from the outside towards the centre, and, roughly speaking, coincide in direction with the bearing of the centre.

I have made measurements of the bearing angle, that is, the wind between the direction from which the wind comes and the bearing of the centre, for nearly every cyclone which has occurred during the past fifteen years. Although there are considerable differences between single measurements, the average of a large number of such measurements gives an angle of almost constant value. This

difference between individual measurements might be expected for a variety of reasons, of which the following are the most important:—

(*a*) Wind observations on board ship are taken on a moving body, and hence the motion of the air recorded is that with respect to the vessel, which may differ considerably from its actual direction with respect to the earth's surface. Thus, if the vessel be going 10 miles per hour, and the air velocity be 60 miles per hour, the error may be as much as a point either way, and will of course be greatest if she is going at right angles to the wind. I have not been able to find in any works of reference any statement of the methods usually adopted by sailors in measuring wind directions. In ordinary weather, and with steady winds, it is probably best observed by noting the direction from which the waves or swell is advancing. In stormy weather, when the winds are strong and ships usually advance slowly, the apparent direction of the wind may be assumed to be the true direction. If the vessel is not advancing more than 4 or 5 knots per hour, this will not introduce any sensible error, but, as already stated, if going 10 miles an hour and at right angles to the wind, and with a strong current aiding her progress, it might introduce an error of a point one way or the other.

(*b*) Sailors usually measure wind to 32 points of the compass. Hence, when the actual direction of the wind varies less than half a point in either direction from one of these points, it can only be estimated by that point. Consequently the rough method of measurement of direction employed allows a range of error not exceeding two half points, that is, of a whole point (or $11\frac{1}{4}°$). This possible range of error is hence relatively large, or the measurement of wind direction on board ship is rough and inexact.

(*c*) The measurement of wind direction on board ship is ascertained by reference to the standard compass. The effect of the strong winds in causing the vessel to lie over towards one side introduces an error in the compass, usually known as 'the heeling error,' the amount of which it is difficult to ascertain, and which is rarely, if ever, allowed for in such cases. The following gives a brief general statement of the heeling error: "The heeling error is an error in the compass of an iron ship due to her heeling to starboard or port. With her head to the *northward* on the starboard tack, easterly deviation is increased; on the port tack, westerly deviation is increased. Heading *south* westerly deviation is increased, on the starboard tack, and easterly deviation on the port tack." I have been unable to find any statement of the amount of deviation or error which may be thus produced, but have no doubt it may occasionally be as much as a point. A measurement of wind direction during strong cyclonic winds may hence be affected to the extent of a point by this cause.

Hence it appears that the measurement of wind direction may be affected by errors of various kinds to a very considerable extent, probably to a limit of two points on either side, or the total range of error may be as much as four points. This, it is hardly necessary to say, is a very wide range of possible error, and it hence makes wind observations on board ships much less reliable and valuable in storms than they would otherwise be.

It will thus be seen that the measurement of wind direction, especially during storms, is liable to several large errors, and it would be hopeless in the present state of these observations to expect perfectly consistent results when comparing single observations. As, however, in a large number of observations the number and magnitude of the errors in one direction will very probably almost exactly counterbalance those in the opposite direction, the mean of a large number of such observations (and of bearing of the centre referred to the wind direction) will probably give a satisfactory and consistent and reliable result. This inference, it will be seen, is borne out by the following results.

The following is the summary of the results obtained for five of the cyclones described in the following chapter. In these I have carefully selected only the most trustworthy observations of wind on board ships, the position of which and of the storm centre at the same time were known with sufficient exactness to give a trustworthy and accurate measurement of the bearing angle :—

Cyclone.	Year.	Average Bearing angle.	REMARKS.
Calcutta	1864	126°	Based on 4 measurements.
Backergunge	1876	118	" 16 "
Midnapore	1874	119°	" 18 "
		124°	" 6 "
False Point	1885	114°	" 5 "
		109°	" 6 "
Akyab	1884	113°	" 8 "

Assigning equal weight or value to each storm these figures give an average of 118° or 10½ points almost exactly for the bearing angle.

I have made measurements for other cyclones, and the average results of these agree almost equally with the preceding.

This result may be summarized as follows :—

To determine the bearing of the centre at any position within a cyclonic torm face the wind exactly, then the centre will be between 10 and 11 points to the right hand (or, more exactly, 10½ points).

The following table gives the direction of the storm centre corresponding with any given direction of the wind in accordance with the assumption that the bearing angle is between 10 and 11 points. It is on the average nearly midway between the two directions given in each case—

Direction of wind.	Probable direction of centre.
N.	Between E.-S.-E. and S.-E. by E.
N.-N.-E.*	„ S.-E. and S.-E. by S.
N.-E.*	„ S.-S.-E. and S. by E.
E.-N.-E.*	„ S. and S. by W.
E.	„ S.-S.-W. and S.-W. by S.
E.-S.-E.	„ S.-W. and S.-W. by W.
S.-E.	„ W.-S.-W. and W. by S.
S.-S.-E.	„ W. and W. by N.
S.	„ W.-N.-W. and N.-W. by W.
S.-S.-W.	„ N.-W. and N.-W. by N.
S.-W.	„ N.-N.-W. and N. by W.
W.-S.-W.	„ N. and N. by E.
W.	„ N.-N.-E. and N.-E. by N.
W.-N.-W.	„ N.-E. and N.-E. by E.
N.-W.	„ E.-N.-E. and E. by N.
N.-N.-W.	„ E. and E. by S.

* It should be carefully remembered that, for reasons given elsewhere, although this direction for north-east winds holds good over the greater part of the Bay, it fails occasionally in the north-west angle of the Bay. With the wind in that direction, the bearing of the storm centre may be in any direction between south-south-west and south-east.

In connection with this general rule sailors will probably wish to know—

(1) whether it holds up to the centre or central calm area;

(2) whether it is the same in all quadrants;

(3) whether the same rule holds in the south of the Bay as in the centre and north.

All that can apparently be inferred from the evidence and information collected up to the present date on these important points is as follows:—

1st.—In the larger cyclones having a central calm area, there is no motion into the calm centre at the earth's surface, and the whole air motion just outside the central area is hence tangential to the central area. The central area is, however, in all cases for which there is evidence forthcoming oval rather than circular in shape, and hence the bearing angle will, even in that part of the cyclone, not be eight points, but will almost certainly on the average be less than 10 points. As these large and intense cyclones are only the development of smaller cyclones, it is probable that the average bearing angle may be less than 10 to 11 points near the centre in the case of the smaller cyclonic storms, but the evidence is not sufficient to establish it with certainty. All investigation up to the present time, however, appears to show that the above general rule holds over the whole of the outer storm area, and also for some distance within the inner storm area. If the sailor be involved in the latter, it will probably be too late for him to do much to extricate himself, and rules are then of little or no use.

2nd.—There are not a large enough number of exact observations to enable a decisive answer to be given to this point. It appears to be true in the south, east, and north quadrants. As already pointed out, there is a very marked tendency for the wind to hang at north-east much longer than is consistent with the above rule in the north-west angle of the Bay when a storm is advancing to the Orissa or West Bengal Coast, more especially in the large storms of September and October. The reasons for this appear to be—

(*a*) The north-east winds of indraught in this quadrant are feeble, and are identical in direction with the normal winds of the period, and hence the actual wind is not a cyclonic wind pure and simple, but is the previously prevailing wind strengthened and slightly modified in direction by the indraught to the storm area.

(*b*) The general character and trend of the Orissa coast, and the lie of the Orissa hills are such as can give a general north-east tendency or direction to all northerly winds blowing across Orissa and the north-west angle of the Bay.

The mariner should most carefully remember the peculiarly treacherous character of the north-east winds at the head of the Bay in the cyclone months of October and November (*vide* page 81).

3rd.—The measurements that have been made indicate that the bearing angle is probably slightly greater in the south than the north of the Bay, but not to so large an extent as to affect the general rule given above.

Hence, with the one important exception noted above (*viz.*, of the north-east winds in the north-west quadrant, in the case of a storm advaacing to the Orissa or West Bengal coast), I believe the preceding rule is exact enough for the ordinary requirements of practical men and sailors who require a fairly definite rule on the subject and have to apply it under circumstances when exact measurement is almost an impossibility. It should, of course, be remembered that there may be real exceptions due either to irregularity in the cyclonic circulation itself, or to features not yet fully recognized, and that there are apparent exceptions, due to errors in the measurement of wind direction on board ships.

As the above rule has not yet obtained general acceptance by seamen and marine authorities, it is desirable to give brief extracts from the writings of various meteorologists showing that it is in accordance with the opinions of those meteorologists in different parts of the world who have made a study of this important subject.

The first is from Mr. Blanford's *Vade Mecum*, published some years ago, chiefly for the use of Indian Meteorological observers. In this he says—

"The degree to which the winds curve inwards towards the centre, or depart from a truly tangential direction, is a point on which further evidence is desirable. Redfield was of opinion that 'it is not probable that, on an average of the different sides, it ever comes near to forty-five degrees from the tangent of a circle; and that such average inclination ever exceeds two points of the compass may well be doubted.' But Mr. Meldrum has shown that, at a consi-

derable distance from the centre, the direction is sometimes radial or nearly so In the case of the storms of the Bay of Bengal, the following rule given by Mr. Wilson is probably a fair generalisation:—'With the face to the wind, the direction of the centre is from ten to eleven points to the right-hand side.' It certainly varies, however, in different storms, and even at different times and in different parts of the same storm, and as the result of a comparison of the charts given by different describers, it seems to me that, on land and in the neighbourhood of land, the direction is considerably more radial or less tangential than on the open sea. I am, however, entirely of the opinion of Mr. Meldrum and Mr. W. G. Wilson, that a rigorous adherence to the rules laid down by Reid, Dove and Piddington,

FIG. 19.

which proceed on the assumption that the winds blow in a tangential direction, and which disregard their spiral convergence, is dangerous in practice and may lead to disaster. A comparison of the two adjoining figures, one of which represents the course of the winds in a cyclone, as assumed in the rules laid down by the above authors, the other that which results from Messrs. Meldrum's, Wilson's, and my own experience, will facilitate a comprehension of the point at issue and its bearings. If figure 19 were a true representation of the course of the winds in a cyclone, a ship, in the position S, with a south-east wind aft, might, by keeping the wind aft, safely run across the path of the advancing storm and escape injury; but if figure 20 be a more accurate representation, then to follow such a course would infallibly lead the vessel into the very heart of the cyclone."

FIG. 20.

Mr. Blanford has lately gone very carefully into the question of the bearing of the centre with respect to the wind direction and has given the following results in *Nature* (Vol. XXXVIII, number of June 21, 1888):—

"1. The mean of 132 observations between latitudes 15° and 22° within 500 miles of the storm centre, gives the angle 122° between the wind direction and its radius vector.

"2. The mean of 12 observations between the same latitudes within 50 miles of the storm centre, gives the angle 123°.

"3. The mean of 68 observations, between north latitudes 8° and 15° within 500 miles of the storm centre gives the angle 129°.

"4. The observations within 50 miles of the storm centre in the south of the Bay are too few to afford any trustworthy result."

Mr. Blanford, from those results, deduces the following practical rules for seamen's guidance:—

"1. In the north of the Bay of Bengal, standing with the back to the wind,

the centre of the cyclone bears about five points on the left hand, or three points before the beam.

"2. In the south of the Bay it bears about four points on the left hand, or four points before the beam.

"3. These rules hold good for all positions within the influence of the storm up to 500 miles from the storm centre. On the north and west the influence of the storm rarely extends to anything like this distance, but it does to the east and south."

Buchan, in his *Hand-Book of Meteorology*, states—

"The relation between the wind direction and bearing of the centre of a barometric depression is what is known as Buys Ballot's 'Law of the Winds.' According to this distinguished meteorologist, if a line be drawn in the direction from which the wind comes, and another from the place of observation to that of least pressure, the angle is generally from 120° to 100°. This is unquestionably the general direction of the wind in storms, but the angle is frequently as large as 135°, especially where the winds become lighter on approaching the central space of least pressure, and on rare and peculiar occasions it is less than 100°. The wind in cyclonic storms blows round the area of low barometer in a circular manner, and in a direction contrary to the motion of the hands of a watch, with, and be this particularly noted, a constant tendency to turn inwards towards the centre of least pressure. Also, the greater the force of the wind at any place, the more nearly is the direction indicated, by the principle stated above, approximated to; and where the directions show any material departure from the general law, such winds are almost invariably light, and consequently more under local influences, which tend to turn them out of their course. Hence in cyclonic storms the winds circulate round the region of least pressure; or, to state it more accurately, the whole atmospheric system appears to flow in upon the central area of low pressure in an in-moving spiral course. This peculiarity is common to all European storms I have yet examined; and it should be particularly noted that it is no mere theory or opinion, but a simple statement of what has been constantly observed."

In the preceding paragraphs a rule has been given by which the bearing of the storm centre can be ascertained approximately from the direction of the wind at any point within a cyclonic storm or cyclone (except perhaps in the immediate neighbourhood of the calm centre). It has also been pointed out that in consequence of certain local peculiarities, this rule partially fails in the north-west angle of the Bay when a severe cyclonic storm or cyclone is approaching directly towards it. The other point for the determination of which the direction of the wind is employed, is the direction of advance or track of the storm.

The wind direction at any instant furnishes approximately the bearing of the storm. The strength and frequency of the squalls (more especially when taken into consideration with the probable character of the storm as determined by the period of the year) (*vide* pages 109 to 124), the rate at which the barometer is falling, and the average force of the wind, are sufficient to enable the sailor to form a rough estimate of the distance of the centre of any cyclonic storm in the Bay of Bengal in which he may be involved. The greater his experience and

the better his judgment the more accurate will his estimate be. Some indications have already been given on these points, and hence will be assumed in the following paragraphs.

When a vessel traversing any part of the Bay of Bengal, more especially in the months of April to December, meets with squally weather, and the squalls become heavier and more frequent, the captain may be certain that he is approaching a cyclonic storm. It may be feeble, but it may be (more especially if it is in the month of May, the last half of September, October, November or December) a fierce and dangerous cyclone, with an inner storm area of hurricane winds. The wind direction will at once tell him in what quadrant he is. The variations of the barometer (if he takes exact observations, and has a properly verified barometer and makes the comparisons suggested in this book, pages 37 to 42) will tell him whether pressure is below the normal, and at what rate it is falling, and hence give him exact indications whether he is in the outskirts of the cyclonic storm and approaching the centre rapidly or slowly, and confirm the conclusions derived from the squally weather. A reference to the storm track charts and rules, &c., given in pages 109 to 124 will also tell him the probable character and track of the storm, so far as it depends upon the season and upon the results of past experience. He will (especially if in command of a steamer) probably continue his course, allowing perhaps his knowledge of the probable position and direction of the storm, &c., to modify his course more or less according to circumstances.

If, however, he finds that his barometer continues to fall, and the squalls and wind become heavier, he may be certain he is approaching the centre, and if he does not ascertain the approximate position and path of the centre, he may, if it is a severe cyclone, be carried, or advance, into the inner storm area. Hence it then becomes necessary to determine these points as accurately as possible.

In order to do this the captain should observe the shift of wind with respect to the motion of the cyclone only. It is hence necessary that he should slow the vessel down and allow it to be at rest as nearly as is possible under the circumstances, and remain in this position until the wind shifts. The change of the wind will give him sufficient indication to determine the path or track, approximately, and (more especially where combined with the inferences based on the other weather signs and data already stated) sufficiently accurately to enable him to determine the best course to adopt to avoid the inner storm area and to pass out of the whole storm area as rapidly as possible and with the last danger to his vessel.

It will be best to illustrate the method by one or two examples. Suppose that the wind is first at west-north-west, and then shifts round to west, the shift not being due to a passing squall, but to a *permanent change in the direction of the air motion or wind.* The direction of the storm would be before the shift of wind very nearly eleven points to the right of west-north-west, or say, north-east. The shift of wind would indicate that the direction of the centre had changed to north-north-east. Hence, if the vessel had remained at rest during this interval, the shift of wind would show that the direction of the centre had changed from north-east to north-north-east by its own motion, and hence that the storm was

advancing in some westerly direction to the north of the vessel. The direction could be obtained still more exactly by taking into consideration the character of the weather during the interval before which the shift of wind was observed. If the weather became more threatening and the squalls heavier, it is evident the centre is approaching the vessel, and hence the course will, in this case, be probably about west. If no marked change occurs in the weather, then the centre is probably marching directly across, *i.e.*, at right angles to the mean bearing of the centre, or its track is probably about west-north-west. If, on the other hand, the weather is improving and squalls are becoming lighter, then it is almost certain the centre is not only passing across in a westerly direction to the north of the vessel, but passing away from it, and hence marching in a more northerly direction or in a north-west to north-north-west direction. The following diagram (Fig. 21) illustrates roughly these remarks:—

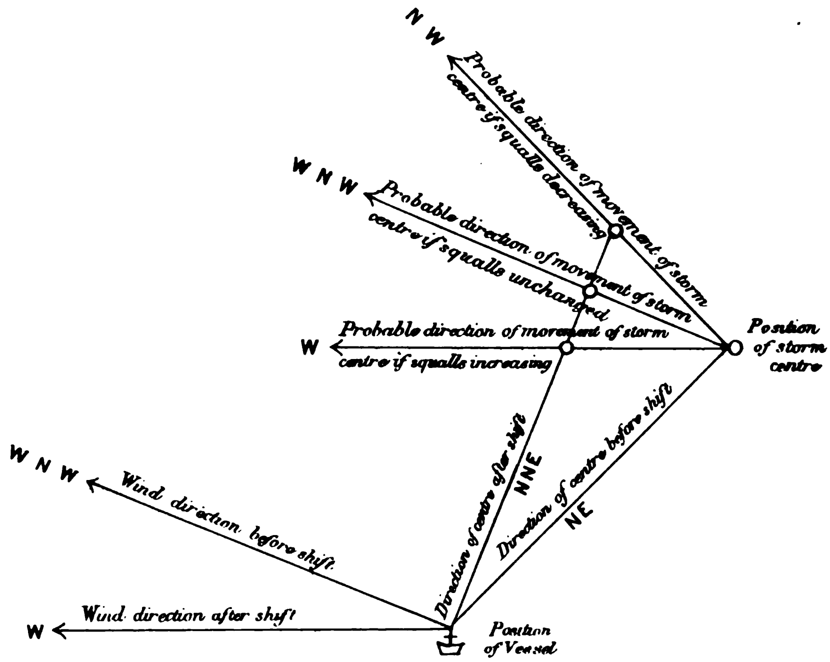

FIG. 21

If, on the other hand, the wind shifted from west-north-west to north-west, or veered instead of backing to west, as it was assumed to do in the previous case, the direction of the storm centre before the shift of wind would be north-east to north-east by east, and after the shift of wind would be east-north-east to east by north.

The direction of motion would be hence in some easterly direction across to the north of the vessel. If the weather got rapidly worse (much more than might be expected during the approach towards the centre in the south-west quadrant of the storm), then the storm centre is almost certainly also approaching the vessel and therefore probably advancing in a southerly to south-

south-easterly direction of the vessel. If the weather is practically unchanged, then it is advancing in a south south-east direction, and if improving, in a south-east or east-south-east direction.

The following table will enable any one to determine from the wind, and shift of wind, the approximate direction of motion or track of the centre of a cyclonic storm (that is, the direction towards which it is advancing) in the three possible cases:—

(1) When the squalls are decreasing in strength.
(2) When they are unchanged in character and frequency.
(3) When they are increasing in frequency and intensity.

The table explains itself—

Direction of wind before shift.	Bearing of centre between	Wind shifts to	Track of centre (moving to)		
			If squalls are decreasing in force and frequency.	If squalls unchanged.	If squalls increasing in force and frequency.
N. . .	E.-S.-E. & S.-E. by E.	N.-N-W. N.-N.-E.	N.-N.-E. S.-S.-W.	N. S.-W.	N.-N.-W. W -S.-W.
N.-N.-E. .	S.-E. & S.-E. by S.	N. N.-E.	N -E. S.-W.	N.-N.-E. W.-S.-W.	N. W.
N.-E. . .	S.-S.-E. & S. by E.	N.-N.-E. E.-N.-E.	E.-N.-E. W.-S.-W.	N.-E. W.	N.-N.-E. W.-N.-W.
E.-N.-E. .	S. & S. by W.	N.-E. E.	E. W.	E.-N.-E. W.-N.-W.	N.-E. N.-W.
E. . .	S.-S-.W. & S.-W. by S.	E.-N.-E. E.-S .-E	E.-S.-E. W.-N.-W.	E. N.-W.	E.-N.-E. N.-N.-W.
E.-S.-E. .	S.-W. & S.-W. by W.	E. S.-E.	S.-F. N.-W.	E.-S.-E. N.-N.-W.	E. N.
S.-E. . .	W.-S.-W. & W. by S.	E.-S.-E. S -S.-E.	S.-S.-E. N.-N.-W.	S.-E. N.	E.-S.-E. N.-N.-E.
S.-S.-E. .	W. & W. by N.	S.-E. S.	S. N.	S.-S.-E. N.-N.-E.	S.-E. N.-E.
S. . .	W.-N.-W. & N.-W. by W.	S.-S.-E. S.-S-W.	S.-S.-W. N -N.-E.	S. N.-E.	S.-S.-E. E.-N .-E.
S.-S.-W. .	N.-W. & N.-W. by N.	S. S.-W.	S.-W. N.-E.	S.-S.-W. E.-N.-E.	S. E.
S.-W. . .	N.-N.-W. & N. by W.	S-S.- W. W.-S.-W.	W.-S.-W. E.-N.-E.	S.-W. E.	S.-S.-W. E.-S.-E.
W.-S.-W. .	N. & N. by E.	S.-W. W.	W. E.	W.-S.-W. E.-S.-E.	S.-W. S.-E.
W. . .	N.-N.-E. & N.-E. by N.	W.-S.-W. W.-N.-W	W.-N.-W. E.-S -E.	W. S.-E.	W.-S.-W. S.-S.-E.
W.-N.-W. .	N.-E. & N.-E. by E.	W. N.-W.	N.-W. S.-E.	W.-N.-W. S.-S.-E.	W. S.
N.-W. . .	E.-N.-E. & E. by N.	W.-N.-W. N.-N.-W.	N -N.-W. S -S -E.	N.-W. S	W.-N.-W. S.-S.-W.
N-N.-W.	E. & E. by S.	N.-W. N.	N. S.	N.-N.-W. S.-S.-W.	N.-W. S.-W.

It may be noted that a portion of this table does not apply practically to the Bay of Bengal, as storms only advance in directions between west and north-east. Hence some of the changes of winds given in the table will not be observed in the Bay of Bengal. It appears, however, to be desirable to give the table in its most complete form.

It should also be noted that the directions of the wind in this table are only given to sixteen points and that the tracks given are only approximate. It would be easy to give a table for 32 points, but it is thought better to test this table by experience before extending it and giving it the appearance of greater precision than it is at present entitled to. Any one who understands the principle upon which it is constructed can of course draw up a table for 32 points. It is advisable that every one using the table in a storm should employ the principles on which it is drawn up and work out the track. Modifying the result by any special considerations which his experience may have suggested to him, more especially by any important weather indications not taken into account in drawing up the table.

This table is drawn up, and the previous rules have been given, on the supposition that the storm advances approximately in a straight course over the Bay. A reference to the chart will show that this supposition holds good in the great majority of cases. The storm track charts (Plates xvi to xxiv) give the tracks of about 110 storms. Of these only four recurved to any considerable extent in the Bay of Bengal, *viz.*—

Storm of 9th to 14th November 1883, which recurved from north-west through north to north-north-east.

Storm of 28th to 7th December 1883, which recurved from north-west through north to north-east.

Storm of 13th to 17th May 1884, which recurved through north to north-east.

Storm of 24th to 26th October 1884, which recurved from north through north-north-east to north-east.

The storm of 14th to 24th November 1886 which crossed the Peninsula and passed out into the Arabian Sea recurved there from west-north-west through north-west and north-north-west to north and north-north-east.

Other examples might be given from earlier storms. One of the most noteworthy was the great Backergunj cyclone of October 1876, which recurved from north through north-north-east to north-east.

The data given above show that out of 110 storms in the Bay of Bengal four recurved, or about one out of every 30. Hence the recurvature of storms is of rare occurrence in the Bay of Bengal (probably much more so than in the Arabian Sea), and the problem of determining the path of a storm is hence in the great majority of cases in the Bay comparatively simple. Also, if a storm recurves in the Bay, all previous experience shows that it will almost certainly recurve towards the east, and generally from north-west, north-north-west or north through north-north-east to north-east. If it recurves very slowly and fairly regularly over a considerable portion of its course, it will not affect to any appreciable extent the determination of the position of the centre and the direction of its advance at that instant, so that the same rules apply as in the ordinary cases. When a storm recurves, its rate of advance is always more or less diminished, and if the recurvature is rapid, its advance is usually very considerably diminished, and the storm may remain almost stationary for some hours. Hence there will be, during such an interval, very little or no shift of wind, and the chief indication of recurvature is hence the tendency for the winds to hang much

longer in one direction than is usual in ordinary storms of the period. In such a case if the vessel be moving slowly or lying-to, there will probably be little change in the height of the barometer or strength of the squalls, in this respect differing from the indications of a cyclone approaching directly towards the observer, when also there is little or no shift of wind It is not possible to give general exact rules to the sailor for his guidance in this matter. He should however recognize that, if he is in the west quadrant of an approaching cyclonic storm in the Arabian Sea, and runs to the north-west or north, it is possible that the cyclone may recurve and advance in the same direction and pass over him. Similarly, in the Bay of Bengal, a vessel leaving the Hooghly, knowing that a cyclone is passing northwards up the Bay, might by steaming to south-east advance straight towards the centre of the storm if it began to recurve to north-east. Whereas, if she remained in the river until the storm was approaching the coast, and its course at the head of the Bay was known with certainty, she might in such a case take advantage of the winds in the western quadrant and run quickly down the Bay.

To sum up, storms occasionally recurve in the Bay. In such cases they always recurve towards east, the usual change being from north-north-west or north to north-east. About one storm in 30 recurves, and as about 10 storms occur on an average every year, an average of one storm in three years recurves. It is not possible, with the present knowledge, to give simple rules by which a sailor may determine from his wind observations (unless he lies-to much longer than would be desirable or probably even possible) whether a distant and approaching storm is recurving or not. It should, however, be remembered that when storms are recurving theirrate of motion decreases, the shift of wind takes place very slowly, and little or no change occurs in the character of the squalls or weather to a stationary observer.

Rate of advance of cyclones.—The rate of motion of cyclones varies very greatly, not only in different storms, but also at different periods in the same storm. In the earlier stages of cyclonic storms in the Bay, they usually advance slowly and increase their rate of motion for some time and until they are fully formed. Also, when approaching the coast they not only occasionally increase in intensity, but also move more and more rapidly. The Backergunj cyclone, for example, which marched at an average rate of about 10 miles up the north of the Bay, increased its velocity to 20 to 25 miles during the last 8 or 12 hours when approaching the mouth of the Megna.

The following gives data for some of the more important storms :—

Storm.	Chief features of rate of motion up the Bay.	
Calcutta cyclone of October 1864.	Average rate of motion—	
	From noon of 2nd to noon of 3rd . . .	9 miles per hour.
	" noon of 3rd to noon of 4th . . .	9 " "
	" noon of 4th to midnight of 4th . .	10 " "
	" midnight of 4th to 10 A. M. of 5th . .	10 " "
	" 10 A. M. of 5th to noon of 5th . .	18 " "
	" noon of 5th to 5 P. M. of 5th . .	15 " "

Storm.	Chief features of rate of motion up the Bay.
Burdwan and Midnapore cyclone of October 1874.	The average rate of motion from forenoon of the 13th until the evening of the 15th was 6¼ miles per hour. The velocity increased to about 10 miles per hour as it approached the Bengal Coast.
Backergunj cyclone of October 1876.	From noon of 27th to noon 30th the average motion per hour=4 miles— Noon 30th to 7-30 A. M. 31st . . . . . 9 miles per hour. 7-30 A. M. 31st to 1 P. M. 31st . . . . . 12 " " " 1 P. M. 31st to 4 P. M. 31st . . . . . 13 " " " 4 P. M. 31st to 6 P. M. 31st . . . . . 15 " " " 6 P. M. 31st to 8 P. M. 31st . . . . . 18 " " " 8 P. M. 31st to 4 A. M. 1st . . . . . 22 " " "
Madras cyclone of May 1877.	Average rate of motion— From noon of 15th to noon of 16th . . . . 3 miles per hour. Noon 16th to noon 17th . . . . . . 3 " " " Noon 17th to noon 18th . . . . . . 6¼ " " "
Akyab cyclone of May 1884.	Average rate of motion— Noon 14th to noon 15th . . . . . . 6 miles per hour. Noon 15th to noon 16th . . . . . . 8 " " " Noon 16th to 2 A. M. 17th . . . . . 9 " " " 2 A. M. 17th to noon 17th. . . . . 10¼ " " " Noon 17th to 9 A. M. 17th . . . . . 15 " " "
False Point cyclone of September 1885.	Average rate of motion— Noon 19th to noon 20th . . . . . . 3¼ miles per hour. Noon 20th to noon 21st . . . . . . 8 " " " Noon 21st to noon 22nd . . . . . 14 " " "
Balasore cyclone of May 1887.	Average rate of motion— Noon 21st to noon 22nd . . . . . 2 miles per hour. Noon 22nd to noon 23rd . . . . . 2 " " " Noon 23rd to noon 24th . . . . . 4¼ " " " Noon 24th to noon 25th . . . . . . 6 " " " Noon 25th to 4-30 A. M. 26th . . . . . 8¼ " " "

The preceding table shows that the rate of motion of cyclonic storms differs very considerably even for storms of the same class, and also for the same storm at different periods of its existence. In the earlier stages of cyclones and cyclonic storms in the Bay, the velocity is generally less than 4 miles per hour. After they have fully formed, they advance in some cases with a velocity, which is uniform during the remainder of their progress at sea; but, in other cases, with a velocity which increases rapidly as they approach land. The average velocity of storms fully formed appears to be from 10 to 12 miles per hour, and this is, perhaps, the best rule for the sailor to assume. Several severe storms of recent years have advanced at the rate of 15 miles when approaching land, and the Backergunj cyclone travelled with the very great velocity of about 25 miles per hour across the mouth of the Megna. There appears to be no direct relation

between the intensity of a storm and its rate of progress, and no general rule has yet been suggested which will enable the sailor to estimate from such observations as he usually is able to take during a storm its rate of motion.

Brief Summary of Chapter.—Cyclonic storms very rarely occur in the Bay of Bengal during the months of January, February and March. The cyclone season extends from April to December, during which period south-west winds bring up cloud and rain to a part or the whole of the Bay. During a considerable part of this period, or from the 15th June to the 15th September, cyclonic storms are of frequent occurrence, but they are never very extensive or violent. They only form near the head of the Bay, and by far the larger proportion pass westwards or west-north-westwards across the Orissa Coast. They cause a high sea in the north-west angle of the Bay, and give heavy westerly to southerly gales in the north of the Bay. During the remaining two periods of the cyclone season, *viz.*, from the 1st April to the 15th of June, and from the 15th of September to the end of December (usually known as the May and October transition periods) storms are of less frequent occurrence. The majority of the storms of these two periods (about three out of five) are neither large nor violent, and are similar in character to the cyclonic storms of the rains. The remaining storms of these two transition periods (about two out of every five) are very dangerous and intense cyclones, as they have an inner storm area of hurricane winds, a very high and confused sea and strong currents around a central area of light airs and calms.

It is desirable that sailors navigating the Bay of Bengal should avoid, so far as is possible, the strong winds and high sea of all cyclonic storms: but it is especially desirable that they should avoid the inner storm area of the intense cyclones of the two transition periods. The weather is of so stormy a character in the inner storm area that no vessel, however strongly she may be built, and however well handled, can hope to pass through it unharmed. On the other hand, considering the manner in which the coasts of India are now warned, the rapid publication of weather reports and charts at the two largest ports Calcutta and Bombay, as well as the extending knowledge of the laws of storms, it is hardly too much to say that there is little excuse (unless under very exceptional circumstances) for the captain of a steamer who drifts or runs into the inner area of a severe cyclonic storm. By utilising the information at his disposal, and by the exercise of judgment and prudence, he should, in the open sea, be able to avoid the inner portion of the storm area and to select a course which will keep him out of the right advancing or dangerous quadrant (more especially if he be near the west coast of the Bay), and will take him into the manageable quadrant or semi-circle of the storm.

In order to do this, it is necessary he should be able to ascertain as early as possible when a cyclonic storm has formed and is in existence in the part of the Bay he is navigating.

The indications of a distant cyclonic storm in the Bay of Bengal are as follows, in the order of their importance :—

A.—General Indications (always observable)—

1st—The occurrence of a succession of squalls which increase in frequency and intensity as the storm area is approached.

2nd—Barometric indications, including—

(*a*) The fall of the barometer more or less below its normal height.

(*b*) The continued fall of the barometer (allowance being made when necessary for change of position of the observer) as he approaches the cyclonic storm. The fall of the barometer is ***never*** rapid except in the inner storm area which sailors in their own interest ought never to experience.

3rd—General appearance of the sky and weather. It is not possible to state these indications very definitely. Many of them are given in two small works published by two members of the Calcutta Pilot Service, Messrs. Elson and Lidstone.[1]

B.—Occasional Indications observable only under favourable circumstances—

1st—The appearance of a peculiarly dense heavy bank of clouds on the horizon. This is most frequently observed in the northern quadrant, where skies are clear or lightly clouded in front of the cyclonic storm.

2nd—Peculiarly dark-red or coloured sunrises and sunsets. These are most frequently noticed to the west, north-west, north or north-east of the storm area.

3rd—The occurrence of a heavy swell proceeding outwards from the cyclone which is fairly regular even at long distances from centre. This is more especially the case in the northern and western quadrants, where it is least affected by the swell due to the wind. The swell becomes higher and more confused as the storm is approached.

When the occurrence of squalls, the sky appearances, barometric and other indications show that a cyclonic storm is in existence in the Bay, and the weather is becoming more threatening (due either to the approach of the storm or to its increasing intensity), the mariner should proceed without unnecessary delay to determine the direction and path of the storm.

The direction or bearing of the centre is obtained from the wind direction in the manner described in pages 128-29. This direction should coincide approximately with the direction of the swell due to the cyclone (if any), and also with the direction of the cyclonic bank of clouds on the horizon (if visible). The swell comes from a direction a little to the left of the direction or bearing of the centre. The indications of the bank of clouds, and of the swell, &c., should only be used to confirm the direction or bearing of the centre as obtained from the wind direction. The mariner (if leaving the Hooghly) should also remember that the wind hangs unusually long at north-east in the north-west angle of the Bay when a cyclonic storm or cyclone is approaching that part of

[1] These books are entitled "The Sailor's East Indian Sky Interpreter and Weather Book" and "Some Practical Observations and Cyclones in the Bay of Bengal," and can be procured from Messrs. Thacker, Spink & Co, Publishers, Calcutta.

the Bay, and hence that the ordinary rule for finding the centre may be out as much as two or three points. As already pointed out, no rule based on wind direction alone for the bearing of the centre can be exact or satisfactory, for the measurement of the wind direction on board ship is itself liable to considerable errors, more especially in stormy weather.

Finally, when he has ascertained the bearing of the centre, he should proceed to ascertain its probable track. In order to do this the vessel should slow down or be hove to, and the first *permanent* shift of wind (evidently due to the motion of the cyclonic storm or cyclone only) will, more especially when considered in connection with the weather, enable him to ascertain the track or course of the cyclone. The method of doing this is explained in pages 133-34.

CHAPTER III.

BRIEF ACCOUNT OF SIX TYPICAL BAY OF BENGAL CYCLONIC STORMS.

The present chapter gives a brief account of six typical cyclonic storms in the Bay, *viz.*—

(1) The Calcutta cyclone of October 1864.
(2) The Backergunj cyclone of October 1876.
(3) The Midnapore cyclone of October 1874.
(4) The False Point cyclone of September 1885.
(5) The Akyab cyclone of May 1884.
(6) The cyclonic storm of 26th June to 4th July 1883.

The first two storms are examples of the largest and most intense storms which occur during the October transition period. The third and fourth storms are examples of the smaller, but equally intense, cyclonic storms which occur at the head of the Bay at the commencement of the October transition period. The fifth is an example of a storm generated during the first large advance of the south-west monsoon current up the Bay, and is remarkable for its peculiar path. The sixth is an example of the numerous class of cyclonic storms of the rains proper, and is a typical and representative example of the more severe storms of that class. The tracks of these six cyclonic storms are given in Plate xxix, at the end of the book.

THE CALCUTTA CYCLONE OF OCTOBER 1864.

The following history of this cyclone is compiled from the valuable report drawn up by Colonel Gastrell and H. F. Blanford, Esq. The report is confessedly imperfect, as meteorological observations were taken at only about half a dozen stations in India in 1864.

Weather previous to the storm.—For some days previous to the formation of the cyclone (that is, from the 28th of September to the 1st of October) pressure was above the average, and was slowly and steadily rising at the coast stations of Chittagong, Calcutta, Madras, and also at Kandy in Ceylon. Also the differences of pressure exhibited by these stations were comparatively small, or pressure was approximately uniform over the Bay.

	Barometer reduced to sea-level.		
	September 27th.	September 29th.	September 30th.
Calcutta	29·90	29·84	29·85
Madras	29·92	29·89	29·90
Chittagong	29·93	29·88	29·90

At the end of the month of September pressure was about an eighth of an inch above the normal. Winds were very light, unsteady and variable at

Calcutta, Chittagong and Madras, and probably over the whole of the north of the Bay and in Bengal. Little or no rain was falling in Bengal and the humidity was slightly below the average. These conditions continued over the north of the Bay and in Bengal during the whole period while the cyclone was being formed in the centre of the Bay. Ships' logs establish that strong south-west winds blew over the whole of the south of the Bay for some days before the commencement of the storm. They also show that in the neighbourhood of the Andamans, dark, squally, rainy weather set in shortly before the storm. This squally weather appears to have commenced on or about the 27th September, but did not apparently develop much until the 1st of October, when the weather became rapidly more threatening. The wind directions given in the logs of the vessels passing up the Bay at the time indicate that there was no cyclonic movement of the air on the large scale on the morning of the 1st, although the weather was squally and very threatening in appearance. They also prove that the change from irregular disturbance and squally weather to general cyclonic conditions of air movement took place during the next 24 hours, *i.e.* on the 1st and 2nd, but was not fully completed before the evening of the 2nd.

October 2nd.—The observations taken on board three vessels and at Port Blair (in positions covering an area of about 100 miles east and west, and 150 miles north and south from Lat. 12½°N. to 14½°N. and Long. 90½°E. to 91½°E.) show very clearly the existence of cyclonic motion over that area on the 2nd, and not before. The logs state that squalls became more frequent and intense during the day, and that a "deluge of rain" was falling on that day over a part, at least, of the area. The barometer had fallen very little at sea (not more than ·05" on the 1st and morning of the 2nd) and was actually rising at Port Blair, where it was at its normal height at 10 A.M. of the 2nd and higher than it had been for some days previously. The observations on board two of the ships nearest to the centre of wind convergence and indraught on the 2nd (*viz.* the *Conflict*, which was in about Lat. 13½° N. and Long. 90° E., and the *Moneka* in Lat. 12½°N. and Long. 90°E. at noon) show that the weather moderated very considerably during the afternoon of the 2nd, and that the sea went down. These ships were not more than 100 to 150 miles from the centre of the area in which the storm was being generated. The *Conflict*, nearest to it, had light variable winds with squalls during the morning. Apparently there was at that time a clearly marked tendency for the storm to decay and the cyclonic movement to be broken up. It is not possible from the observations to infer the cause of this halt in the progress and growth of the storm. The observations of the 3rd show that this tendency speedily passed away, and that the storm increased very rapidly in extent and intensity on that day. Whether, as the authors of the Calcutta Cyclone Report suggest, this was due to one centre filling up and disappearing, and another being formed immediately, or shortly afterwards, in front of the previously existing storm centre, is a question which cannot be decided from the limited information contained in the logs of the three vessels, the *Moneka*, *Conflict* and *Golden Horn*, which give all the information of the storm in the Bay at this time that the authors were able to obtain. So far as can be judged, it would appear that, although the storm was developing from the initial stage of squally, disturbed weather, it had not yet passed beyond that stage.

October 3rd.—The logs of five vessels enable the position and character of the disturbance on the 3rd to be determined. The three vessels previously referred to, *viz.*, the *Conflict*, *Moneka* and *Golden Horn*, had advanced 100 miles northward, but were still in the southern quadrant of the storm. Two other vessels, the *Nile* and *Clarence*, were at a considerable distance to the west and north-west of the centre. The *Golden Horn* had hard squalls with heavy rain in the morning and a deluge of rain during the afternoon. The *Conflict* had frightful squalls with very heavy rain, and the *Moneka* heavy gusts to calms with rain falling "as in a solid mass." The centre at noon of the 3rd was in about Lat. 16° N. and Long. 90½° E. The storm area was much larger and now included a nearly circular area from 300 to 400 miles in diameter. The barometer was also falling rapidly at and near the centre, but as no vessel was within the inner storm area on the 3rd, it is not possible to state the amount of the barometric depression at this period. The disturbance now began to influence the weather in Bengal. Winds which had hitherto been chiefly south (although very variable) veered round and blew steadily from north or north-east, but were as yet very light. Light cirrus clouds also began to appear in the course of the afternoon, and weather which had hitherto been fine, clear and pleasant became cloudy and slightly unsettled.

October 4th.—The position of the centre at noon of the 4th is fixed by information taken from the logs of eight vessels in the north of the Bay. The storm centre was now advancing to the mouth of the Hooghly (in a north-north-westerly direction) at the rate of 9 miles an hour. The centre was in Lat. 18° 50′ N. and Long. 88° 30′ E. at noon, and at that time two vessels, the *Golden Horn* and *Clarence*, were not more than 35 miles from each other and were on opposite sides of the storm centre. The *Clarence* had "furious squalls from north, with torrents of rain," and the *Golden Horn* a heavy southerly gale with a deluge of rain. The barometer at the centre was apparently not below 29·00 at noon of the 4th, judging by the barometric readings taken on board these two vessels. Stormy weather had now extended to the Bengal coast, and during the afternoon and evening of the 4th winds strengthened rapidly, rain-squalls came up and became more and more frequent, the sea rose, and the sky and weather assumed a very threatening appearance. At the Sandheads, and entrance to the river, the fury of the storm was chiefly felt on the night of the 4th. The centre passed to the east of False Point at a distance of about 80 miles shortly before midnight. The Pilot Brig *Chinsurah* ran southwards during the afternoon, and passed a little to the west of the centre about midnight, at which time her barometer read 28·57, having fallen one inch since the previous noon. The Pilot Brig *Foam*, like the *Chinsurah*, ran southwards, having slipped her cable at 4 P.M. She passed to the west of the centre but nearer than that vessel. Her log states that at 8 P.M. it was blowing a violent hurricane. At 11 P.M. the quarter-boat was washed away and the vessel thrown on her beam ends, when the main-mast was cut away. The barometer at that hour stood at 27·96″ and remained at that height until midnight, when it began to rise. From midnight to 5 A.M. of the 5th the wind blew with hurricane force and then began to abate.

October 5th.—The cyclone recurved slightly to east after midnight of the 4th and advanced in a northerly direction, and at the average rate of 10 miles per hour, to the Bengal coast west of Saugor Island. The centre passed over the *Alexandra* Steam Tug, which was lying at anchor off Saugor Light-house, between 8 A.M. and 9 A.M. of the 5th. The following extract is from the captain's log:—"At 4 A.M. the wind shifted suddenly to north-east, blowing in furious gusts, accompanied by pelting driving rain and seas over all. On coming head to wind, the engines were set going with seven revolutions, at full power. About 8 or 9 A.M. it became suddenly calm, with a heavy confused sea, the sun appearing at this time for a few minutes. Got the head of the steamer to northward, having only then discovered that the cable had parted. The frightful roar of the hurricane, the heavy sea breaking fore and aft, and the steamer lying on her beam ends prevented anything being noticed with regard to the cable before. The steamer's head was now to wind and the engines doing their best. The calm interval lasted about three quarters of an hour. During the calm, being apparently in the vortex of the hurricane, several land birds were falling about the decks, some dead. Got soundings in 7 fathoms. Supposing the steamer to be in Saugor Roads, kept on going to the north and east, but could sight no land; secured hatches, and at the end of the calm a thick mist and heavy rollers seemed coming from north-west, accompanied by a moaning sound, which was immediately followed by a sudden blast from the north-west, throwing the steamer on her beam ends and burying her in a sheet of foam to the top of the funnel. The port jolly-boat blew on board and carried away the standard compass. The starboard boat was under water and was torn from the davits. All that could be done was to try and keep her near the wind, while heading to northward by means of the engines only, as it was impossible to think of letting go another anchor. After blowing till 2 P.M. with the most intense fury and constant heavy rain, the wind shifted to the south-west; the weather broke suddenly, water became smooth, and land appeared on the port beam. Finding the vessel in 4 fathoms, made preparation to anchor; situation very doubtful and coast strange; 3 P.M., water suddenly shoaled to 2 fathoms; the steamer struck before the engines could be reversed and in less than an hour was quite dry. About 9 P.M., as the tide made, backed off to the westward into smooth water and anchored in 4 fathoms for the night. In the morning the position was found to be off the Piply Sands in Balasore Roads." The vessel had hence been carried to the westward by the force of the current upwards of 30 miles.

Before proceeding to give the history of the cyclone after it crossed the coast, it is desirable to give the experience of two vessels, the *Proserpine* and *Nile*, which were at nearly equal distances from the centre, but in opposite quadrants, in illustration of a very important point, *viz.* the strength of the storm in the eastern quadrant as compared with the westward quadrant. The *Proserpine* was proceeding from Calcutta to Akyab, and was, when nearest to the storm on the 4th, upwards of 180 miles from the storm centre. On the morning of the 4th it was blowing a great gale from the east with increasing sea. The gale increased rapidly, and the sea rose with wonderful rapidity. By 3 A.M. it became too powerful for the steamer to make headway against, and she

finally drifted under the force of the winds and currents, the helm being wholly unmanageable. The following extract from her log of her subsequent experience is extremely interesting:—"6 P.M.—The gale still increasing; vessel rolling very heavily; lost the galleys; water increasing in the engine-room; kept it under as well as we were able with the ship's pumps. *Midnight.*—Sea increased to a frightful extent. Vessel labouring heavily. All the men completely knocked up. 1 A.M.—Gale still increasing, immense heavy seas breaking over the forecastle and foredeck. 3-30 A.M.—On sounding the fore compartment discovered that there was 3½ feet water in her; took off the hatch and set all hands at work to pump and bale the water out; found the lower deck washed up, and beams and planks, &c., dashing about below, threatening to go through the side or water-tight bulkheads; sent all available hands to the pumps, as the water in the engine-room was increasing very fast; the gale appeared to be now at its height, the vessel plunging into the seas, leaving over two feet of water on the upper deck; commenced cutting away the lower part of the bulwarks, and after great difficulty succeeded in getting several holes made which slightly relieved the immense pressure forward; cleared away the boats as much as we dared, and put water and provisions into them, as we fully expected the vessel to go down under us. Threw everything we could overboard in order to lighten her forward, the vessel being totally unmanageable the whole of this time. *Noon.*—The wind was now to the south a little, a fearful sea running. 1 P.M.—The weather began to improve a little. All were employed at the pumps, but were so exhausted as to be scarcely able to keep them going. Ship rolling and straining very severely; sea not appearing to decrease in the least. *Midnight.*—Weather seems clearing up, but there is still a fearful sea rolling. 1 A.M.—Wind and sea decreasing."

The *Nile* was in the western quadrant and at a distance of 160 miles from the centre at noon, or 20 miles nearer than the *Proserpine* when she was nearest. The following is the account of the weather she experienced as given in her log:—"OCTOBER 4TH, A.M.—Confused sea; ship pitching at times. *Daylight.*—Weather unsettled, wind north-west; a head sea. *Forenoon.*—Wind north-west, freshening at times, with a north-north-east sea. *Noon*—Wind north-north-west; weather cloudy. Sea uneasy. P.M.—Squally with rain. *Sunset.*—Wind west-north-west; high north sea. *Midnight.*—Moderate west breeze; ship plunging heavily to a high sea."

This contrast between the weather to the north-west, west, and south-west of the centre, and that to the south-east, east, and north-east, is a very prominent feature in the cyclonic storms of the Bay, and should be carefully remembered by sailors.

The centre of the cyclone struck the coast near Contai. It blew at that station a north-east gale from 4 A.M. to 7-45 A.M. of the 5th, when the gale was at its height. The barometer fell from 28·95 at 8 A.M. to 28·025 at 9-45 A.M., when the wind suddenly fell to a calm which lasted until 11 A.M., after which the storm recommenced from the south-west, blowing a perfect whirlwind.

The history of the land passage of the cyclone will be briefly given. The next station after Contai over which the centre passed (of which there is an account)

is Tumlook. A strong north-easterly breeze prevailed from the morning of the 4th until 4 A.M. of the 5th, when the wind increased rapidly in force. It was blowing a hurricane at 9 A.M., and from that time to 11-30 A.M. it continued to increase in fury. Between 11-30 A.M and noon the storm wave came in, and the water rose speedily until noon, when the centre of the cyclone passed over the station. At that time the wind was due east. The central calm lasted rather more than half an hour, after which the wind came down from the opposite quarter. It began perceptibly to decrease in force about three hours afterwards, and at 6 P.M. was only blowing a little fresh from west.

The centre passed over Santipore in the afternoon at 5 P.M. The wind at that station blew during the early morning with no great force, but gradually increased till noon, when it was blowing a strong gale. The force of the wind intensified rapidly for some time, blowing from the same direction as hitherto, *viz.* east. The wind changed from east to north-east at 3 P.M., and was at the height of its violence at that time, tearing down the largest banian trees. Hurricane winds continued until 5 P.M., when the storm ceased entirely for 45 minutes and commenced again, blowing first from the west and then from the south-west. The storm centre was, at the time of its passage over Santipore, about 25 miles to the west of Calcutta. The area of destruction did not extend more than 35 or 40 miles to the west of the central track, and the storm was not felt at all beyond about twice that distance. To the east of the path of the centre, the extent over which the storm extended was considerably greater, and, so far as can be judged, at least twice as great.

After passing over Santipore the storm recurved slightly to the east, and advanced between Burdwan and Krishnagor and between Murshedabad and Kooshtea. The following gives a brief account of the weather as observed at Kooshtea :—" The storm began here with heavy rain and moderate winds from the north-east about mid-day of the 5th. As the day advanced the rain gradually decreased, but the wind increased steadily, veering round still more to the eastward with fitful gusts which blew the rain into a mist. By 9 P.M. the wind was about due east, and it was now evident that something more than an ordinary gale was blowing. From this time to about 11 P.M. the storm was at its height. With very few exceptions every hut and tree was blown down, gardens destroyed, &c. The wind, while doing all this mischief, gradually veered round from east to south, and blew hardest from about the south-east When it got fairly to the south its force was reduced, and by the time it had a little westing in it (about midnight) the storm began to abate. The storm hence lasted about twelve hours altogether."

October 6th.—The accounts of the storm after this date appear to indicate that it was breaking up, and that the cyclonic circulation was less regular than before, and probably resolving itself into smaller eddies. It is almost impossible to reconcile the different accounts except on some such supposition. The following gives an account of the weather at Rampore Beauleah :—"OCTOBER 5TH.—7 A.M. Cloudy, with wind from north-east. 10 A.M., cloudy and drizzling; wind north-east. 1 P.M., clouds flying low, occasional showers, wind north-east, and blowing stronger. 2 P.M. blowing stronger; not much rain; wind still north-east; baro-

meter 29·40″. 4 P.M., wind increasing; barometer 29·38″; 6 P.M., blowing strong and in gusts; more rain; Barometer 29·33″. 8 P.M., wind very much increased, and the gusts stronger; barometer 29·30″; wind north-east by north. 9 P.M., blowing a strongish gale; gusts at times very severe; barometer 29·27″; wind veering to north-north-east. 10 P.M., blowing a perfect gale; wind in severe gusts accompanied by a sound like distant thunder; wind north; trees beginning to fall; barometer 29·20.″ 11 P. M., a very severe gale, blowing steadily, with, at times, very severe gusts; wind north; barometer 29·15″. OCTOBER 6TH.—*Midnight*, gale at its highest; no walking against the wind, which had shifted back to north-east by north. Trees falling; raining hard; barometer 29·00″. 1 A.M., wind north. 2 A.M., wind north-west, the gusts less frequent, but the steady blow very strong; barometer 29·00″. 3 A. M., still blowing hard, but not so severe, barometer 29·3″. The gale abated after 3 A.M., and at 10 A.M. there was sunshine, and wind from south-west."

The storm passed near Bogra, where it was comparatively feeble, and finally broke up on approaching the western escarpment of the Garo Hills.

The storm wave.—The most remarkable feature of the Calcutta cyclone of 1864 was the storm wave. It was nearly full moon on October 5th. The storm wave arrived at the mouth of the Hooghly a little after 10 A.M., high water being at about noon. The storm wave apparently advanced more slowly up the Hooghly than the ordinary tidal wave, and hence at Calcutta the storm wave was only about an hour in advance of full tide. The wave therefore occurred under conditions favourable for producing a very large effect.

The enormous accumulation of water in the north-west angle of the Bay when the storm centre was crossing the coast was very strikingly shown by the experience of the ship *Martaban*. She lay at anchor in Saugor Roads on the evening of the 4th, when it was blowing a strong gale. At 5 A.M. of the 5th the wind had increased to a hurricane and the ship began to drag her anchors. The fore- and topgallant-masts were carried away at 9-30 A.M., the main-mast at 10 A.M., and the fore-topmast at 10-30 A.M., by which time the ship was a wreck on deck. The centre shortly after passed over the vessel, and was followed by a terrific wind that blew for a short time. The weather began to abate at 12-20 P.M., and cleared up rapidly. As soon as it cleared up sufficiently to enable the pilot to ascertain his position, he found that the vessel was to the west of the Jellingham sand, and had drifted over some of the most dangerous sands in the river without touching or shoaling any water. The lead was constantly used, and the ship never shoaled at less than 7 fathoms. The pilot hence estimated that the storm wave must have risen at least 40 feet to have carried him across those sands.

One point in connection with the storm wave is of great interest. It is very unlike the tidal wave, which rises gradually, and which only on favourable occasions gives rise to, and is accompanied by, a small sudden advance of a wave or wall of water or bore. In the case of the storm wave there is, for some time, as the storm centre approaches the shallow waters at the head of the Bay, a vast accumulation or rise of water. This head of water finally gives rise to a sudden and overpowering advance of the accumulated mass of water up the river, and an almost equally rapid inundation of the low-lying grounds near the sea-

shore. The following extract from the account of a Civilian who was overtaken by the flood due to the storm wave whilst on his way to Midnapore illustrates this feature of the storm wave on the Bengal coast:—

"I took shelter in a hut. . . . . There was a most curious sound which was exactly like the letting off steam from a steamer, but on a gigantic scale, and then the cyclone burst on us in all its fury. First we saw my palkee being rolled along, like a barrel, round and round. Then the roof of our hut was lifted up like the lid of a box, and immediately the walls crumbled away. Soon I heard my bearers talking in a frightened manner with a few stray villagers. They then nervously asked the time. I told them just past twelve noon. They said that at half past twelve a high bore was to be expected. We watched as much as we could, for it was difficult to see 20 yards off through the driving rain, or rather mist. Sure enough, though I did not see any actual bore, the water *all at once suddenly rose as if by magic, and steadily rolled towards us.*"

The storm wave flooded the whole of the low-lying ground in the neighbourhood of the Hooghly as far up as Akra in Kidderpore, and the lower reach of the Roopnarayan river to above Koila Ghât, sweeping all before it by the suddenness of its rush and by the immense volume of water. The following gives a brief account of the destruction of life in the submerged districts:—

Loss of life during the flood (approximate)	50,000
Loss by disease due directly to the flood	25,000 to 30,000
TOTAL LOSS OF LIFE DIRECTLY AND INDIRECTLY CAUSED BY THE STORM .	80,000

The destruction of shipping in the Port of Calcutta appears greatly to have exceeded that on record for any previous storm. There were, on the 5th October, 195 vessels in port, either at their moorings or at anchor in the stream. The moorings were held by anchors of 65 and 70 cwt.; and the chains laid down after the cyclone of 1842 were of the heaviest construction. At the same time new posts of sâl wood for shore fastenings, 22 feet long by 2 feet square, were fixed along the river bank. It appears, however, that the moorings were of insufficient length, and thus the rise of the river due to the storm wave brought an additional strain on the chains, already stretched to their utmost under the pressure of the cyclone winds, and caused the ships to break loose in masses, after which they drifted before the blast, carrying before them many of those that had ridden out the storm so far safely in midstream, and were grounded, a mass of confused wreck, with cargo-boats, lighters, and smaller boats of every description, on the sands of Goosery, Seebpore and Cossipore. Of the whole number above mentioned, only 23 were uninjured on the morning of the 6th October; 39 were damaged but slightly, 97 damaged severely, and 36 were totally lost or had suffered so severely as to become constructively wrecks. Among these last were the *Asemia*, 1,179 tons, the *Govindpore*, 1,357 tons, the *Lady Franklin*, 1,187 tons, the *Lewchew*, 854 tons, the *Ville de St. Pierre*, 379 tons, and the *Vespasian*, 919 tons, which sank off Calcutta, the *Baron Renfrew*, 904 tons, whi[illegible] was lost near Diamond Harbour, and the *Ally*, 665 tons, a cooly

emigrant ship, which foundered with the almost total loss of the crew and emigrants, 15 miles below the same station. A considerable quantity of cargo, both on board the ships and on cargo-boats, was either swept away or had to be sacrificed to lighten the vessels. Wrecked property, to the estimated value of R57,000, was rescued by the Police in the town and suburbs of Howrah alone, but the Superintendent of Police was of opinion that, in spite of all exertions, a vast amount was taken and concealed by the ryots, many of whom it was said, far from suffering by the cyclone, became suddenly wealthy. The banks of the river at Cossipore were, for weeks subsequent to the cyclone, thickly strewn with masses of jute beneath and among the pack of stranded wrecks.

The Peninsular and Oriental Company's steamer *Bengal*, 2,185 tons, was landed high and dry on Shalimar Point, where she remained a conspicuous object for more than two months, when she was at length restored to deep water by cutting a dock around her, and towing her out at vast expense. The *Hindustan*, receiving hulk, the property of the same Company, was partly driven on shore, but foundered next morning.

No reliable estimate has been formed of the total value of the shipping and cargo lost or damaged in the port. It was stated at the time to be about two million pounds sterling, butthis was apparently no more than a vague guess at the amount, and much over-estimated. Mr. R Stewart, a partner of Messrs. Gladstone and Wylie's house, considers that this estimate more nearly represents the gross value of the shipping property at stake, and that the actual loss was considerably under one million sterling.

Brief summary of chief facts.—The storm was formed during the 1st and 2nd of October in about Lat. 13° N. and Long. 91½° E., or about 100 miles to the west of the Andamans, and marched in a straight north-north-west course to the mouth of the Hoogly, and thence advanced into Central Bengal, curving round to north-north-east and north-east in its progress through South-west and Central Bengal. The following gives the position of the storm centre at various intervals during the storm and the rate of motion :—

Time.	Position of Storm Centre.		Distance travelled since last previous position.	Rate of motion during interval.
	Latitude.	Longitude.		
			Miles.	
October 2nd, noon .	13° 15′ N. . .	91° 40′ E. .	...	......
„ 3rd „ .	16° N. . .	90° 15′ E. .	215	9 miles per hour.
„ 4th „ .	18° 50′ N. .	88° 30′ E. .	220	9 „ „
„ „ midnight	20° 20′ N. .	87° 45′ E. .	115	10 „ „
„ 5th, 10 A.M. .	Contai . .	...	96	10 „ „
„ „ noon .	Tumlook . .	...	35	18 „ „
„ „ 5 P.M. .	Santipore . .	...	75	15 „ „
„ 6th, 1 A.M. .	Near Rampore Beauleah.	...	75	9 „ „

Its rate of motion hence apparently never exceeded 10 miles per hour in the Bay of Bengal, and it did not increase its speed as it approached the Bengal Coast, in which respect it differed from the Backergunge, Midnapore, False Point,

and other intense cyclonic storms of recent years. Its rate of motion however increased very rapidly for some time after it crossed the Bengal Coast, and it advanced at a rate of at least 15 miles through West Bengal. It decreased to its former rate of about 10 miles per hour in passing through Central Bengal.

The lowest observed reading of the barometer during the storm was 27·96" (corrected), taken on board the *Foam*.

The central calm area on the evening of the 4th and morning of the 5th when it was probably greatest, was elliptical-shaped, and from 10 to 15 miles in diameter.

The extracts from the logs of vessels that are given above (more especially the *Proserpine* and *Nile*) show most fully that the strongest winds extended much further to the south and east than they did to the north and west.

The following gives the few reliable data of the direction of the wind as related to the bearing of the storm centre :—

Ship.	Date.	Distance and bearing of Centre.	Wind direction.	Bearing Angle.
Conflict . .	October 4th, noon	280 miles west by north .	S.-E.	146°
Nile . . .	„ „ .	160 „ north-east .	W.-N.-W.	112°
Clarence . .	„ „ .	30 „ east south-east .	N.	112°
Proserpine . .	„ „ .	190 „ south-west	E.	135°

The reliable observations of positions of vessels involved in this storm and of wind-force are very few in number, but, such as they are, they give a mean bearing angle of 126°, or 11 points very nearly.

The Backergunge Cyclone of October 1876.

The Backergunge cyclone was the largest and most destructive to life that has occurred during the present century. A smaller cyclone, which formed during the first week of the month of October 1876, passed over Vizagapatam on the 8th, recurved, and marched between the coast and the hills of Ganjam and Orissa into Bengal, where it finally broke up on the evening of the 10th or morning of the 11th in the neighbourhood of the Himalayas in North Behar and Bengal.

Weather previous to the formation of the cyclonic storm.—The barometer rose rapidly after the dispersion of the Vizagapatam cyclone, and was during the next fortnight very considerably above its normal height. Thus, the means for the period 10th to 20th October at the following stations differed from the normal means by the following amounts :—

Madras	·10"	in excess.
Port Blair	·15"	„
Akyab	·13"	„
Calcutta	·09"	„
Patna	·06"	„

The excess was thus greatest in the east and south-east of the Bay, or over that portion of the Bay where the cyclone was very shortly afterwards formed. The mean temperature of the air was from 2° to 7° below the average of the season in Northern India, but was slightly above it at Port Blair and Madras, and probably over the south and centre of the Bay, where the weather

was very sultry. Fine dry cool weather, with cloudless skies and light airs, prevailed almost without interruption in Northern India. During this period the winds in Bengal, which had been previously southerly, shifted round to their cold-weather directions, and the winds and weather at the end of the third week of October were such as prevail when the north-east monsoon is fully established over the north of the Bay. Pressure was remarkably uniform, the difference of pressure for example between Nancowry and Madras being in fact less than would be got by taking a barometer from the ground floor to the first floor of a house, and between Nancowry and Roorkee (on the Punjab frontier) not more than would be obtained by transferring a barometer from the ground floor to the roof of a three-storied building in Calcutta (45 feet in height).

The weather in the south and centre of the Bay at this time is described in the logs of three vessels. The ship *Lightning* crossed the equator on the 12th in Long. 88½° E., and advanced very slowly northwards up the centre of the Bay, reaching Lat. 9° 17′ N. on the 23rd. During this interval she experienced very light winds and calms, with showers of rain and hot sultry weather, the sun being so hot as to boil the pitch out of the seams of the deck. The *Tennyson* crossed the Equator in Long. 89° 40′ E. on the 13th and was in Lat. 13° N. on the 26th. She experienced light baffling winds, with heavy rain during the whole of this period, *i.e.* until the 26th, on which day the wind veered to north-east and the weather cleared up. The *City of Venice* passed round Ceylon on the 26th. She had light breezes, and weather was fine and clear to the west and south of Ceylon, and in this respect unlike the weather in the eastern half of the entrance to the Bay. From the 20th to the 27th or 28th the weather in the north of the Bay was of the same character as in Bengal. In the south-east of the Bay, as is indicated by the Port Blair, Nancowry and ship observations, weather was unsettled, and the winds were very variable and unsteady. Much rain was falling, and squalls were of occasional occurrence. No change took place in that area of slightly unsettled weather until the 24th and 25th, when the first indication of cyclonic movement of the air on the large scale began to be exhibited. The cyclonic movement was comparatively feeble between the 24th and 26th, and showed no strong tendency to increase and concentrate.

The following extracts from the logs of ships give the character of the weather in the south and centre of the Bay from the 24th to 26th :—

The *Tennyson* crossed the Equator on the 13th, in Long. 89° 40,′ and advanced northwards over the area in which the storm was immediately afterwards formed. She had light baffling winds chiefly from west with heavy rain until the 26th, when, in Lat. 13° N., the weather cleared and the wind veered to north-east.

The *Forfarshire*, proceeding up the Bay to Calcutta, was in Lat. 11° 30′ N., Long. 90° 30′ E., on the 25th. The weather on that day was clear and fine, and the north-east monsoon had apparently set in.

The *Lightning* advanced during the period October 23rd to 26th from Lat. 9° 17′ N. to about Lat. 16½° N., Long. 90° E. During these four days she had fine weather and light north-east to east-north-east winds. There were, however, during the whole of this period in the south-east quarter, disagreeable-looking

cumulus and nimbus clouds which appeared to the captain to be indicative of a storm. Every evening there was much threatening lightning in an archway from the south-east up to about 40°, then crossing over to the south-west.

The above brief accounts of the weather confirm the land and island observations, and show that there was a very slight tendency on the 23rd and 24th to deficient or low pressure to the west of the Nicobars and south-west of the Andamans, over which weather was evidently unsettled and threatening. Pressure was fairly steady, but the tendency continued to be exhibited on the 25th. The *Tennyson*, which traversed this area on that day, had light winds and a steady barometer. She passed out of it on the 26th in Lat. 13° N. and then experienced ordinary north-east monsoon weather until she was overtaken by the cyclone on the 30th. The *Lightning* passed also through the area in which the cyclone was initiated on the 23rd and 24th, or two days earlier than the *Tennyson*. She had very hot, fine weather, very light winds and occasional showers. The weather was slightly unsettled at the Nicobars and Andamans. Winds were, as in the Bay, light. The average daily velocity from the 23rd to the 25th at the Nicobars was only 50 miles, or barely 2 miles per hour. Light showers fell at intervals, and skies were more or less clouded. In fact the weather was almost identical with that experienced by the *Lightning*, and hence no important or marked change had occurred in the interim in the sea area. On the evening of the 25th and morning of the 26th a rapid and significant increase took place in the force of the wind at the Nicobars, which was coincident with the commencement of rapidly increasing cyclonic circulation on the large scale. The history of the storm proper hence dates from the evening of the 25th.

History of the Storm.—*October 26th* —No ships were in the storm area on the 26th. The *City of Venice*, which was passing round the eastern coast of Ceylon, experienced light breezes and heavy rain, with occasional severe squalls and unsettled weather. The amount of wind registered at Nancowry for the 24 hours preceding 10 A.M. of the 26th was 254 miles, and for the next 24 hours was 310 miles. The weather was hence rapidly changing in character.

October 27th.—The history of the cyclone will now be given chiefly by means of extracts from the logs of ships involved in it. A remarkable feature in the history of the storm is that, although there were an unusually large number of vessels in the Bay passing up to the Hooghly, not a single vessel was involved in the storm centre. This was largely due to the fact that the cyclone recurved to the north-north-east and advanced towards the mouth of the Megna, so that vessels bound for the Hooghly were all in the western quadrant and at some distance from the centre. Hence, also, neither the greatest barometric depression at the centre nor the full weight of the storm near the centre is known, and can only be inferred from the magnitude of the storm wave which followed and broke upon the coast districts at the mouth of the Megna. The observations of the 27th show that there was a clearly-marked depression, the centre of which was to the west of the Andamans in Lat. 10° N. and Long. 89° E., and that over this area winds were cyclonic in direction, but were as yet of moderate intensity. The ships *Empire of Peace* and *British Sceptre* were to the south-east of the central depression during the day. The former experienced thick cloudy weather, much rain and moderate winds from south-

south-west to south-west. The latter (nearer to the centre) had strong breezes during the day and a deluge of rain. Here, as in the great majority of storms in the Bay, there is very strong evidence that heavy and torrential rainfall was a very prominent feature of the storm, even before the setting in of strong cyclonic winds and the complete establishment of the cyclonic circulation. The *Arabia* to the west of the centre had constant rain and occasional squalls. The ships *Tennyson* and *Forfarshire* (250 miles to the north-north-west) had fine clear weather with moderate north-east winds. Moderately strong cyclonic winds were blowing at Port Blair and Nancowry. Skies were thickly clouded, and heavy rain fell during the day.

October 28th —The cyclone developed rapidly in intensity and extent on the 28th and 29th, and was, on the afternoon of the 29th, a large and dangerous storm. The weather was of the usual character. Torrential rain fell over a large part of the area of depression, and frequent squalls occurred, increasing in intensity, and the winds near the centre increased in force until they finally blew with hurricane fury and violence. The *British Sceptre*, 200 miles to the east-north-east of the centre on the 28th, had torrents of rain (alternately warm and cold), the *Empire of Peace* (180 miles to the east-north-east at noon of the 28th) strong breezes with much rain, and the *Allahabad* (150 miles to the east-north-east) constant rain and heavy squalls. The *City of Venice*, to the west-south-west of the centre at noon, had frequent squalls of wind in the morning. At noon there was a fresh breeze, with heavy squalls. At 8 P.M. the wind had increased to a fresh gale, and at midnight it blew a hard gale, with hard squalls.

The weather had improved considerably at Nancowry, but was still showery and windy at Port Blair.

October 29th.—The centre of the depression advanced during the 24 hours preceding noon of the 29th to Lat. 13° N., Long. 89° E., or a distance of about 120 miles, and was nearly 150 miles due west of Port Blair. The area of depression at mid-day of the 29th covered a large area, extending from Long. 6° N. to Lat. 18° N., and from Long. 92° E. to Long. 83° or 84 E. in which winds were of force 6 or upwards, and squalls were experienced. The ship *British Sceptre* (250 miles to the north-east of the centre at noon of the 29th) experienced torrents of rain and hard squalls, the *Allahabad* (270 miles to the north-east) constant rain with very heavy squalls, and the *City of Venice* (280 miles to the west-north-west of the centre) had an unceasing gale with continuous rain during the morning. The captain of the *City of Venice* states that the winds and squalls increased in force, and that at 4 P.M. it blew a hard gale, with furious squalls. The logs of several vessels which were approaching the mouth of the Hooghly at this time describe the weather as threatening in the north of the Bay, and show that strong winds and squalls were felt as far north as Lat. 18° N. in the morning. Before nightfall the weather had become unsettled and squally as far north as 20° N., and the appearance of the sky was such as to suggest the speedy occurrence of stormy, dangerous weather.

October 30th.—The full development of the storm took place during the evening of the 29th and morning of the 30th. The land observations and the ships' logs show that on the morning of the 30th violent cyclonic motion of the air (in which winds of force 9 to 12 with frequent hard squalls) extended

over an elliptical-shaped area (250 miles by 200 miles), the centre of which, at noon, was in about Lat. $14\frac{1}{2}°$ N. and Long. $89\frac{1}{2}°$ E.

The path of the cyclone up the Bay on the 30th and 31st, and the severity of the storm, will be best understood from the experience of each of the vessels involved in the more dangerous portions of the cyclone.

The steam ship *Japan* was running northwards up the west side of the Bay more quickly than the cyclone, and was also approaching the centre on the evening of the 29th. The weather became very threatening, and the gale began to freshen so rapidly that the captain eased the engines. She consequently remained behind the cyclone, and the weather gradually improved. The *City of Venice* was also in the outer storm area at a distance of about 300 miles from the centre at noon. She experienced a hard gale, with fierce squalls, during the evening of the 29th, and at 9-20 A.M. of the 30th the weather was so threatening that the captain turned the ship's head to the south-west for some hours, and thus avoided the intensity of the storm.

The cyclone was at this time advancing northwards at a mean rate of nearly 10 miles per hour.

October 31st.—The steam-ship *Penang* was involved in the storm on the morning of the 31st. She left Calcutta on the 28th and steamed southwards into the teeth of the advancing cyclone. She experienced very rough weather on the 30th. The wind increased rapidly, and the barometer began to fall quickly on the evening of the 30th, and was at its lowest at 4 A.M. of the 31st. At 6 P.M. of the 30th the ship was taking huge seas on board, and the deck midship house and port saloon door were stove in. At 8 P.M. the starboard saloon door was broken in and the saloon flooded with water. At 10 P.M. the engineer and engine-room crew were battened down below, and the fore and main rooms and mizen gaff were blown adrift. At 4 A.M. of the 31st the gig was washed away. Wind and sea were then at their highest and it was impossible to walk or stand on deck. At 7-30 A.M. the whole of the front of the saloon was stove in. The ship lay like a log, with the saloon full of water. All the head-boards, knees and gangways were now washed away. The barometer was at its lowest (29·32") from 4 A.M. to 7-30 A.M., and the weather began to improve at 8. A.M. The ship was, however, found on the 1st to be a perfect wreck on deck and it was judged necessary to put back to Calcutta. The *Penang* was at 7 A.M. of the 31st, when nearest to the centre, at a distance of about 150 miles from it.

The *Scottish Chieftain* encountered the cyclone a little further to the north. She arrived at the head of the Bay on the 29th and was unable to obtain a pilot in conseqnence of the strong winds and heavy sea. She therefore stood off to the south-east on the 30th. The gale (from the north-east) increased rapidly in the afternoon and evening, and the squalls became more frequent and heavy. At 3 A.M. of the 31st the barometer read 29·2". Heavy rain began to fall at 4 A.M., and terrific squalls from the north passed over the vessel. At 8 A.M. it was blowing a perfect hurricane. The sea now washed away everything on deck and filled the cabin. The barometer stood at 29·1" at 10 A.M. The wind was at that time from north and blowing a hurricane, and the ship was on her beam ends. At 11-30 A.M. it was necessary to cut away the foretop-mast.

The barometer was lowest at noon, when it stood at 29·00" (corrected 28·961"). The wind was then terrific, and the lee rails of the vessel continually under water. The weather moderated slowly during the afternoon and evening. The *Scottish Chieftain* was nearest the centre at noon, but was even then probably at a distance of 80 or 100 miles from it.

The *Tennyson* was about 20 miles to the west of the storm centre at 1-30 P.M. on the 31st. She was proceeding up the Bay to the mouth of the Hooghly along the meridian of 89° E. in front of the storm on the 29th and 30th. She had passed through the area in which the storm was generated only a few days previously and began to experience squalls and increasing winds on the afternoon of the 29th. Weather became steadily worse on the 30th, and at 10 P.M. it blew in furious squalls for an hour. This was followed by a brief lull, when a very violent squall from the east-north-east threw the ship on her beam ends until the first rush of the squall was past. The wind blew with hurricane force from the east-north-east from midnight (when the barometer was 29·6") until 9-30 A.M., when it veered gradually to north, and the noise of the wind became a perfect howl. The sails were now torn from their gaskets and went to ribbons in a few minutes. The sea was a scene of the wildest confusion. The ship was thrown on her beam ends, and the sea, breaking on board, swept away everything and left her a wreck on deck. The barometer was lowest at 1-30 P.M., when it stood at 28·15" (corrected reading 28·12"). The weather began to moderate at 6 P.M., and at midnight it had died away to a calm. The top of the sea was blown about during the storm so as to make it impossible to see 20 yards from the ship.

The storm centre at noon of the 31st was moving at the rate of about 12 miles per hour, and was in Lat. 18° 45′ N., and Long. 89°25′ E. at 1 P.M.

The *Annie Fleming* was, at 4 P.M., nearest to the centre, which was at that hour in Lat. 19° 15′ N. and Long. 89° 30′ E., and was about 50 miles to the west of it. She had arrived at the Sandheads on the 29th, but was unable to obtain a pilot. The captain stood off to the south-east on the 30th on account of the weather. At 8 P.M. of the 30th, the barometer was 29·2" and falling rapidly. At 7 A.M. of the 31st, the barometer had fallen to 28·6", and the wind was blowing with hurricane force. At 2 P.M. there was a most terrific burst of wind, which carried away part of the rigging and sails. The ship was now on her beam ends. The barometer stood at 28·5" from 2 P.M. to 4 P.M., when it began to rise and the weather to moderate.

The steam-ship *Thessalus* was about 90 miles to the west of the centre at 4 P.M. She had reached the head of the Bay on the 30th. The captain states that up to early morning of the 31st the barometer gave no indication of anything serious, and did not begin to fall until it was too late to do anything. At 5 A.M. the sea was terrific. At 10 A.M. the sails were carried away, and at 2·30 P.M. the main topgallant-mast was carried away. The sea at that time was wild beyond description, the ship putting her lee side under water at times up to the dead-eyes of the lower rigging, and the wind occasionally made the masts bend like bamboos. The rain fell with such force as to be very painful to the eyes, and made it almost impossible to see. The weather was at its worst at about 4 P.M., when the barometer stood at 29·05". It moderated rapidly after that hour and the sea fell very fast indeed, so that on Wednesday (the 1st

of November) there was not the least indication of a great storm having passed over that part of the Bay.

The *Lady Octavia* and *Palmas* were nearest the centre at 6 P.M., when it was in 19° 45′ N. and 89° 50′, or 90° E., and advancing at a rate of 15 miles per hour in a north-north-easterly direction. The former was then about 25 miles and the latter 35 miles to the west of the centre.

The *Lady Octavia* was, on the 29th, sailing northwards to Calcutta, and was at noon in Lat. 19° 33′ N., and Long. 90° 14′ E. She had heavy rain and variable winds on that day. The weather became rapidly worse on the 30th, and towards evening she was turned southwards. The barometer at 2 A.M. of the 31st stood at 29·8″ (uncorrected). At noon the wind was blowing with hurricane force, and a fearfully high and cross sea running. At 5 P.M. the main topsail blew to pieces. The captain describes his experience of the storm from that hour as follows: "At 5-15 P.M. the fore top-gallant mast parted at the cap; cut away the gear to save the other spars, but was scarcely on deck when away went the main mast, and after it the mizen top-gallant mast, carrying away the top-mast head by the shrouds; lee crojjack and topsail braces gone, and the sails all blowing from the gaskets; main and main topsail braces and the fore and fore-topsail braces carried away. The ship at 5-30 P.M. was pressed down to the lee rails, and nearly all the lee bulwarks washed away, the sea making a clean breach over her and sweeping away everything from the decks. It smashed in the front of the poop and cleared out the cabins, carrying away ship's chronometers, charts, and papers, all the captain's clothing and property, and left nothing belonging to the captain's wife and son (who were on board) but what they wore. The steward and the second and third mates lost everything, and the steward's store-rooms were completely gutted out. The first mate was washed overboard and got his hand hurt among the lee wreck, his fore-finger being cut off by the first joint. He was washed into the fore rigging, and had to cross over to windward by the top and down the weather rigging. The top was then smashed all away, the yards tearing up everything they fetched against. The wind was then blowing with such force that it was nearly impossible to squeeze down between it and shrouds. About this time the lee side of the deck-house was under water, and the whole house gutted, with all the petty officers' and boys' clothing; the starboard side of forecastle and lockers and the cook's galley gutted out; the captain's gig was carried away from the davits, and one davit wrenched off from the side; the starboard life-boat was also swept away from the chocks and the long-boat started from the top of the deck-house; all spare sails were swept out of the sail lockers; boatswain's and carpenter's stores were also carried away. At 7-30 P.M. the lightning began to flash very near, and soon the wind lulled a little and backed into north-west.

"The following were the barometer readings from noon to 5-30 P.M.:—

Hour.	Uncorrected Reading.
Noon	29·50″
3 P.M.	29·10″
3-30 "	28·90″
4 "	28·46″
4-30 "	28·25″
5-30 "	28·15″

"At about 6 P.M. the barometer got broken, and the glass of the aneroid cracked. All the meteorological instruments and books were shortly after broken up and washed away. At 8 P.M. the gale began to moderate and sea to go down."

The experiences on board the ship *Palmas* are equally valuable and interesting. The following gives the most important extracts from her log:—

"Left Negapatam on the 12th October bound for Calcutta, and was near the Eastern Channel light-ship on the 30th. At midnight the barometer began to fall rapidly, and the weather looked very threatening, and all preparations were made for a strong gale. At noon of the 31st it was blowing a hard gale. By this time found it must be an approaching cyclone. The ship was evidently in the north-west quarter of a cyclone, travelling from south-south-west to north-north-east. At 2 P.M. the heavy sea and lurches (assisted by the quantity of water gone below) caused the sand ballast to shift to starboard, giving the ship a heavy list to leeward. With the heavy lurching the 90 fathoms of starboard chain broke adrift, and was thrown on the lee gunwale, and at the same time all the sails and provisions, &c., on the weather side of the fore cabin were thrown to leeward, throwing the ship almost on her beam ends. We slacked away fore and main topsail sheets to try and right her, the fore one blowing away in the act, and had to slack off the main topsail sheets till it blew away. We squared the main and cross-jack yard and put the helm up to try and put her on the other tack to get the low side up, although we were already on the right tack for the cyclone, but the ship would not pay off, but continued to come up as the wind was hauling more northerly and causing the heavy south-south-west sea to break in over our lee rails and poop, and endanger the safety of the ship by knocking against the hatches. When in this position, cut away topgallant back-stays, the masts going over with their gear and fouling the top-sail yards. We could not cut them clear, as all the wire got twisted and turned together. At 4 P.M. the cyclone was increasing; barometer 28·50", the sand still shifting to leeward and putting the ship on her beam ends. I saw then that the next thing to cutting the masts away would be to let go the starboard anchor, and let it run the 90 fathoms chain from the lee side. I went forward with the chief officer and saw all clear, and let it go, taking the 90 fathoms chain with it. The ship then righted a great deal, and less sea came over the rails. We then had a chance to go below to trim some of the ballast, and I sent all hands below for that purpose, leaving the carpenter, sailmaker, and one man on the deck to look out for the hatches and tarpaulins. In the meantime the top-gallant masts and yards were swinging about and cutting the topsails and courses adrift from the gaskets and causing them to be blown away. At 6 P.M., when the barometer stood at 28·20", we had the heaviest blow. The centre of the cyclone was then passing about 40 miles" (this was the captain's estimate and almost exactly correct) "to the eastward, the wind hauling to north-north-west and north-west with fearful vivid flashes of lightning, thunder and rain. At this time the whole of the remains of our sails were blown away. The foretop-gallant yard had by this time got down, end on alongside, and knocked against the side and chafed very much, but could not cut it clear. At 7 P.M., the gale abating, we ceased trimming, the men being all tired and worn out, and the south-south-west sea being then

nearly aft, ship heading up north-east by north and rolling much less. 3 P.M., gale moderating and, the barometer having risen to 28·50", let all hands go to rest and get ready for the next day's work, to clear the wreck and trim ballast. *Midnight* the weather clearing and wind moderating."

The *Neva* was the next vessel in order of time which encountered the full weight of the storm. She was bound from Mauritius to Calcutta and was advancing up the east of the Bay. She had, at noon of the 30th, a strong increasing gale and a mountainous sea from the south. At 8 P.M. heavy squalls, with torrents of rain, passed over the vessel. Similar weather continued during the night, and at noon of the 31st the wind was blowing with hurricane force. The wind became more violent, and at 10 P.M. was blowing with terrific force, and the sails, which had been made fast with extra gaskets and lines, were now all carried away. At 11 P.M. the wind was blowing a terrific hurricane, with tremendous gusts, accompanied with torrents of rain, and the ship was taking in large quantities of water. At 2 A.M. of the 1st the wind began to moderate. At noon she had light breezes, beautiful fine weather, and a very smooth sea.

The British India Steam Navigation Company's steam ship *Moulmein* left Chittagong for Calcutta on the afternoon of the 30th. She hence crossed directly in front of the advancing storm. The following gives the chief details of the storm as experienced on board :—"*Noon of the 31st.*—Wind north-east, with heavy confused sea. 4 P.M.—Wind now blowing a hurricane. 5 P.M.—Fore-topmast carried away. 7 P.M.—Foremast carried away close to deck. Spray blowing right over the ship; standard and steering compasses blown away. 10 P.M.—Wind north-north-east. Funnel carried away. Main topmast carried away. Fires put out and the boiler ran dry. The engines not able to work, and three feet of water in the stokehole, with all pumps choked. The barometer at 8 P.M. was 28·4", the lowest reading taken. From 11 P.M. the wind began to decrease."

The *Allahabad* was about 80 miles from the centre in the opposite quadrant to the *Moulmein* at the time when that vessel was nearest to it. Her log states that "at noon of the 30th, when she was in Lat. 17° 57' N. and Long. 91° 40' E., constant rain was falling, with frequent very heavy squalls. A very heavy swell came up from south-south-west and south-west. 8 P.M.—Weather looked bad and threatening, with every indication of a cyclone. At 11 P.M. it was blowing a heavy gale from east-south-east, and a strong current setting northwards. At midnight it was blowing a very hard gale with constant rain, very heavy squalls, and much lightning to the southward. The squalls increased in force during the morning of the 31st, and at noon the cyclone commenced to blow with great fury and continued with no abatement until midnight. At 8 P.M. the wind began to veer to south-east. At 10 P.M., when the wind was at south-south-east to south, the cyclone was at its fiercest. It was then blowing with inconceivable fury. (The lowest reading of the barometer taken on board the vessel during the storm was 28·9.") The sails were torn from their gaskets, and the canvas in the mizen rigging blown away. The wind began to moderate after midnight, and the sea went down fast, and at noon on Wednesday the weather was beautifully fine."

The centre at 9 P.M., about which time it was nearest to the *Moulmein*, was in Lat. 20° 30′ N. and Long. 90° 25′ E., and had been moving during the previous three hours at the rate of 21 miles per hour in a north-easterly direction. It continued to advance with accelerating velocity, and was at about 85 miles to the west-north-west of the *Neva* at 11 P.M.

November 1st.—One peculiarity of the Backergunge cyclone was the rapid increase in its rate of advance as it marched northwards, more especially on the 31st. During the last five or six hours before it struck the coast it was marching at the mean rate of about 22 miles. It struck the coast at the mouth of the Megna. The centre passed over the island of Huttyah between 3 and 3-30 A.M., over the island of Siddhi between 3-30 and 4 A.M., and over the South Bamni district between 4-30 and 5 A.M. The vortex, or calm centre, appears to have been elliptical-shaped, the largest axis running perpendicular to the direction of motion, and was probably 16 miles in length, whilst the shortest in the direction of motion was from 8 to 10 miles in length.

The later history of the Backergunge cyclone is unusually brief. The centre passed over Noakhally at about 4 A.M. and over Dewangunj at 5 A.M. where the calm interval was very short. It was then advancing in a north-east direction to the Tipperah Hills. They lay at right angles to, or across, the direction of motion of the approaching cyclone, and acted not only as a perfect barrier, but as an obstruction which completely broke up the cyclonic motion before 10 A.M. of the 1st.

The storm wave.—The most remarkable feature of the Backergunge cyclone was the enormous storm wave which it drove over the islands and low lands at and near the mouth of the Megna. The inundation was due to an unusually high tidal wave, followed very shortly afterwards by the storm wave. It was full moon on the evening of the 31st, and there was hence a spring tide, which flooded the low-lying land at the head of the Bay. High water was due at Chittagong at 0-30 A.M., and in the mouth of the Megna from 1 A.M. to 2 A.M. The pressure of the advancing storm wave prevented the tidal and river water flowing off. The storm wave was hence retarded over the shallow water near the entrance to the Megna and accumulated there and finally overpowered the down-flowing waters, and rushed with irresistible force over the islands, and low-lying coast districts, covering them to the depth of from 10 to 30 or 40 feet in the course of a very short space of time, probably less than half an hour. The waters receded very quickly as the storm passed inland and began to break up, and at 8 A.M. they had entirely retreated, after having destroyed all the crops and drowned a very large proportion of the inhabitants. The first estimate of the destruction of life was given as about 200,000. A later, and probably more correct, account puts the loss of life by drowning at 100,000, and the loss subsequently by disease (chiefly cholera), directly due to the inundation, as 100,000. It is therefore probably not too much to say that the storm wave caused directly or indirectly the death of nearly a quarter of a million of people.

Brief summary of chief facts.—The following gives the most important details of the storm :—

The cyclone apparently formed on the 25th, 26th, and 27th to the west of the Andamans in Lat. 10° N. and Long. 89° E., and moved first northwards and then gradually recurved to north-east. The position of the centre at various times and its average rate of motion are given below—

Date.	Position.		Distance passed over since last previous position.	Average rate of motion during interval.
	Latitude.	Longitude.		
27th, noon	10° N.	89° E.	90	4 miles per hour.
28th „	11¼° N.	89° E.		
29th „	13° N.	89° E.	120	5 „
30th „	14½° N.	89½° E.	105	4 „
31st, 1 P.M.	18° 45′ N.	89° 25′ E.	294	12 „
„ 6 P.M.	19° 45′ N.	89° 50′ E.	75	15 „
„ 9 P.M.	20° 30′ N.	90° 25′ E.	62	21 „
1st 3 A. M.	22° 30, N.	91° 0′ E.	144	24 „

One of the more remarkable features of the storm was the very great increase of its velocity on approaching the coast of East Bengal.

It reached the mouth of the Megna about 3 A.M. of the 1st of November. The central calm was then from 15 to 18 miles in its longest diameter, and was probably elliptically-shaped, the longest diameter being nearly perpendicular or oval to the direction of motion.

The cyclone was completely broken up before 10 A.M. of the same day by the action of the hills in Eastern Bengal and South Assam. It extended, at sea over a very large area, blowing with hurricane force, and disabling vessels at a distance of 200 miles from the vortex, and was the most extensive, as well as one of the fiercest cyclones of the present century.

The lowest readings of the barometer observed during the storm were—

28·15″ (uncorrected) on board the *Tennyson* (20 miles to west of centre).

28·15 (uncorrected) on board the *Lady Octavia* (20 to 25 miles west of centre).

28·2″ (uncorrected) on board the *British Statesman* (20 miles west of centre).

28·2″ (uncorrected) on board the *Palmas* (35 miles west of centre).

28·4″ (uncorrected) on board the *Moulmein* (45 miles north-north-west of centre).

It is hence almost certain that the barometer was below 28 inches in the central area, and may have been at least as low as 27·5 inches, or even lower.

The following table gives data of the direction of the wind, the bearing of the centre, and the bearing angle for a large number of cases:—

Position of observation.	Date.	Approximate distance from centre.	Approximate bearing of centre.	Wind direction.	Bearing angle.	Weather.
		Miles.				
Tennyson	27th, noon	350	S.	N.-E.	135°	Fine steady breeze.
Port Blair	"	275	W.-S.-W.	E.	160	Gloomy.
Nancowry	"	350	W.-N.-W.	S.-S.-W.	90	Rain.
Empire of Peace	28th, noon	175	W. by S.	S.-E.	124	Torrents of rain.
Allahabad	"	140	W. by S.	...	...	Heavy squalls.
City of Venice	"	310	E.	N.	90	Do.
Port Blair	"	250	W.	S.-E.	135	Gloomy.
Nancowry	"	400	N.-W. by W.	S.-S.-W.	101	Passing showers.
Allahabad	29th, noon	250	S.-W. by W.	S.-E.	101	Heavy squalls.
Port Blair	"	270	W.-N.-W.	S.-E.	157	Gloomy.
Nancowry	"	475	N.-W.	S.-W.	90	Overcast.
Japan	"	410	N.-E. by E.	W.-N.-W.	124	Squally.
Japan	30th, noon	300	N.-E. by E.	W.-N.-W.	124	Do.
City of Venice	"	260	E.	N. by W.	101	Strong gale.
Nancowry	"	540	N.-W. by N.	S.-W.	101	Passing clouds.
Empire of Peace	31st, noon	125	W.-S.-W.	E.-S.-E.	135	Cyclone.
Japan	"	175	N.-E.	W.-N.-W.	112	Light breeze.

The average of the various values of the bearing angle is 118°, or 10½ points very nearly.

THE MIDNAPORE CYCLONE OF OCTOBER 13TH TO 17TH, 1874.

This was an example of a cyclonic storm of small diameter and extent, but of very great intensity at and near the centre. The information derived from ships' logs respecting its origin and early march is scanty, but yet sufficient to enable its chief features to be determined with approximate accuracy.

Weather previous to the storm.—For some days previously (from 1st October) the winds in Bengal and Orissa and over the north of the Bay were extremely light and variable, and calms were of frequent occurrence. The barometer, as usual at the commencement of October, rose steadily, and almost without interruption from the 1st to the 10th, when it was either normal in

amount or slightly above the average value of that period, as is shown by the following statement:—

Station.	Actual pressure at 10 A.M. on 10th.	Normal pressure at 10 A.M. on 10th.	Variation of actual pressure from normal.
Madras	29·82	29·82	Normal.
False Point	29·85	29·84	·01 inch in excess.
Saugor Island	29·84	29·82	02 " "
Calcutta	29·84	29·84	Normal.
Dacca	29 85	29·83	·c2 inch in excess.
Chittagong	29·87	29·84	·03 " "
Akyab	29·86	29·85	·01 " "
Port Blair	29·87	29·83	.04 " "

During the first ten days of the month the weather was fine, with passing clouds. Showers fell locally in Bengal, but no general rain was received over any large area. The rainfall due to these local showers diminished in amount up to the 10th, when it practically ceased until the advent of the storm, so that the period from the 10th tothe 14th was almost rainless in Northern India. Fine clear weather prevailed over nearly the whole of Bengal at this time. The temperature was from 1° to 2° above the normal, and winds died down, especially in West Bengal, to the lightest airs. Thus, at Burdwan on the 10th only 24 miles of wind were recorded by the anemometer (the average daily amount in October being 55 miles pei day), and at Berhampore on the 11th only 8 miles, the average daily amount for the month being 45 miles. Mr. Wilson, Meteorological Reporter, Calcutta, at the time, in his Report on the Cyclone sums up the character of the weather in the following words: "It was such as is usual at the time of year, light variable winds or calms prevailing, with a clear transparent atmosphere, and a blue sky, partially covered with cirrus and cumulus."

The weather in the south-east of the Bay was very different, and such as invariably precedes the formation of a cyclone. From the 1st to the 10th it was unsettled and squally at Nancowry. Moderately strong south-west monsoon winds (on the average 50 per cent. stronger than the normal winds of the season) prevailed during the whole of this period. The sky was almost always overcast, and the prevailing cloud was nimbus. Heavy rain fell on the 6th and 7th. From the 10th the weather began to clear at Nancowry. At Port Blair, on the other hand, the weather was showery, with moderate south-easterly or variable winds from the 1st to the 10th. The winds increased considerably in force from the 11th to the 13th, when they were almost double their normal strength. Weather was very unsettled and squally, and heavy rain fell on the 11th and 12th. These facts show that squally disturbed weather prevailed over a portion of the Bay, and that at this period, immediately before the beginning of the storm, the squally weather was first experienced in the south of the Bay and extended very slowly northwards from the 1st to the 12th, when the centre of the area of squally weather was probably in the latitude of Port Blair.

This squally weather was quite distinct from the cyclonic storm, although such weather very frequently precedes, and forms the first stage in the origin of

a cyclone. This is established by the fact that the meteorological information contained in the logs of vessels shows most clearly that there was no general cyclonic movement of the air before the evening of the 12th in the south or centre of the Bay. Thus the ship *Ireshope* in Lat. 17° 8′ N. and Long. 89° 45′E. on the 10th had fine weather and variable winds from south to west and calms with light occasional squalls. The *Udston* on the 11th in Lat. 11° 12′ N. Long. 91° 6′ E., had light breezes from west-north-west to west-south-west, with clear and warm weather and a steady barometer, and on the 12th when she was in Lat. 12° 48′ N., Long. 90° 56′ E. at noon, or about 120 miles to the west-north-west of Port Blair, she experienced the following weather:—"Early morning, wind changed to east for a short time with very heavy rain, then veered again to the west. At 8 A.M. rain ceased; a light breeze from west-south-west. *Noon,* fresh winds with very unsettled appearance. *Afternoon and evening,* sharp squalls and heavy rain. *Midnight,* wind unsteady from west and north-west, squalls and heavy rain." This vessel was a short distance to the south of the area in which the cyclonic circulation and storm was generated during the next 24 hours. Her log is very interesting, as it proves most clearly that a period of unsettled weather and of variable winds, interrupted by squalls, increasing in strength, preceded the formation of the storm proper and formed in fact the preliminary stage.

History of the storm.—During the next 24 hours the transition took place from irregular, diffused, indefinite disturbance, characterized by squalls, occasional rain and variable unsteady winds, to a clearly marked regular cyclonic movement of the air on the large scale, with its characteristic features.

October 13th.—The history of the storm proper hence begins with the 13th of October. During the night of the 12th the weather became rapidly worse, and a definite cyclonic circulation was initiated, the centre of which at noon of the 13th was in about Lat. 16° 40′ N., and Long. 90° E. The *Udston* in Lat. 15° 17′ N., Long. 91° 6′ E., had west or west-south-west winds, with sharp squalls and heavy rain in the morning and in the evening a fresh south-south-east gale with squalls and drizzling rain. The ship *Chanticleer* in Lat. 17° 41′ N. Long. 88° 36′ E. at noon had north-easterly winds with squalls and heavy rain. About 100 miles further north the *Ireshope* and *Patrie* had winds from north to north-east, fine weather and a smooth sea with occasional gusts during the morning. In the afternoon weather became squally and a violent squall passed over the *Patrie* at 2 P.M. The wind at 10 A.M. was steady from south-west at Nancowry and Port Blair. The barometer began to fall at first slowly, but in the afternoon and night more rapidly, and at noon of the 14th there was a small area of about 100 miles in diameter in which the barometer was from ·2″ to ·5″ below the normal height of the season, and in which the air was in rapid cyclonic motion and squalls of considerable intensity were occurring at frequent intervals.

October 14th.—The centre of the disturbance was now marching in a north-north-westerly direction with a velocity of about 7 miles per hour, and its position at noon of the 14th was in about Lat. 18° 50′ N. and Long. 88° 45′ E. The *Ireshope,* about 80 miles to the north-north-west of the centre at noon of the 14th, experienced the following weather:—"*Morning*—Increasing squalls, north-east

winds. *Evening*—Terrific squalls and heavy gale. *Midnight*—Wind veered from north to north-west in a terrific squall." The change of the wind direction was of course due to the northward advance of the cyclone past the vessel. It may also be noticed that this was an example of the shift of the wind, which frequently occurs during squalls in cyclonic storms in the Bay.

The *Patrie* was about 60 miles further north. Her log states that in the morning the wind was from north-north-east and freshening. At noon she had heavy rain and continued squalls, in the afternoon very violent and continued squalls from the north-east, and at midnight the wind was from the east-north-east and blowing with hurricane force.

The *Udston* was advancing northwards up the east side of the Bay more rapidly than the cyclone, and was hence brought into the eastern quadrant during the afternoon. Her account of the weather is as follows:—*Morning*—Overcast and dull, with hard squalls and rain. Wind from south-east. *Noon*—Increasing gale, with terrific squalls. *Afternoon*—Wind east, strong gale and heavy squalls. *Evening*—Wind east, terrific gale, with fearfully high sea.

The storm centre appears to have passed over the Arab ship *Fussel Kureem* on the morning of the 14th. Her position at noon of the 13th by observation was 17° 48′ N. Lat. and Long. 88° 33′ E. At that hour the weather was gusty, with showers of rain. The weather became rapidly worse during the evening and at midnight. At 7 A.M. of the 14th she had the wind from the east and the jibboom was carried away. At 8 A.M. the wind shifted suddenly to the west, at 9 A.M. to south-west, and at 10 A.M. to south. The vessel during this period lost all her sails. In the afternoon the sea was very confused and made a clear breach over the vessel. The barometric observations on board the *Fussel Kureem*, if they may be trusted, show that the barometer in the central calm area was not below 29·0″ at noon of the 14th. The sudden shift of wind from east to west at 8 A.M. is the only evidence that she passed through the centre. There is, however, no mention in her log of any lull, such as is usually experienced in the calm centre.

The various observations indicate that the storm on the 14th was of comparatively small extent, but that it had now developed into a very intense, fierce, and dangerous cyclone. The inner storm area of considerable barometric depression and of hurricane winds, was not more than about 50 miles in diameter. The outer storm area of strong winds, with more or less violent squalls, but of slight barometric depression, was not more than 200 to 250 miles in diameter. Outside of this area the weather was but slightly influenced. For example, the pilot vessel *Coleroon* had fine weather and a moderate north-east wind at 6 A.M. The floating light-vessel *Comet* (stationed at the Mutlah), the *Meteor*, stationed at the Eastern Channel, and the steamer *Sir John Lawrence*, passing down the river Hooghly had light to moderate airs and hot sultry weather until about 2 P.M., when squally cloudy weather, with winds increasing rapidly in force, set in. They were not more than 150 to 200 miles north of the storm centre at 2 P.M.

October 15th.—The observations of the 15th establish that the centre at 1 P.M. was in Lat. 21° N. and Long. 87° 45′ E. It had therefore advanced in a north-north-west direction during the previous 24 hours at an average rate of 7 miles

per hour. The character of the weather in the storm area at this time is best understood by extracts from the logs of the vessels over which the inner storm area, or calm centre, passed during the day. The *Patrie* experienced the full weight of the cyclone on the morning and forenoon of the 15th. The wind was blowing with hurricane force on the previous midnight, and the sea rising very rapidly. The barometer stood at 29·65″, but was falling rapidly. At 5 A.M. it stood at 28·94″. The tempest was then raging with great fury and increased in violence until 9 A.M., when the barometer had fallen to 28·15″, after which the calm centre passed over the vessel. At the end of 15 minutes the storm commenced again to blow with greater violence than before. The wind continued to blow with hurricane force until 5 P.M., when the barometer had risen to 29·45″ and the weather began to moderate.

The storm centre passed over the pilot vessel *Cassandra* apparently very shortly after it left the *Patrie* behind in its advance northwards. She was 5 miles south-west of the Eastern Channel light-ship at 8 P.M. of the 14th, and was then tacking to the south-east. She appears, however, to have drifted considerably to the westward during the night, and the barometer began to fall rapidly after midnight. Between 7 and 8 A.M. of the 15th several of the sails were carried away. At 8-30 A.M. a strong gale was blowing with violent squalls from the east. At 10 A.M. the barometer had fallen to 27·9″, and a lull, lasting for about an hour, commenced. At 11 A.M. the wind shifted to the west and heavy squalls struck the vessel. At 11-15 A.M. the wind was blowing a hurricane. The barometer was rising rapidly at noon, but the wind blew with tremendous force for upwards of two hours afterwards, and did not begin to moderate until after 3 P.M.

The floating light-vessels at the Eastern Channel, Lower Gaspar, and Upper Gaspar stations felt the storm severely in the eastern quadrant and were all driven off their stations. The pilot vessel *Coleroon*, attempting to put to sea, was driven to the westward and caught right in the centre of the storm. She was at anchor at the pilot station near the Eastern Channel light-vessel on the 14th. The weather was fine in the early morning, but at noon the sky became cloudy and the wind freshened. In the afternoon there were frequent squalls with heavy rain. The wind veered from north-east to east-north-east at 5 A.M. of the 15th, and was blowing a fresh gale. At 7 A.M. the wind was increasing fast and the sea rising. The *Coleroon* now attempted to put to sea under reefed foresail and staysails. She appears to have drifted to the westward and dragged her anchors for some time previously under the force of the current and strong winds. The storm now increased with unusual rapidity and was blowing with hurricane violence at 8 A.M. of the 15th, when the barometer had fallen to 29·52″. At 9 A.M. it was blowing a furious hurricane with blinding rain-drift, and a very heavy sea. The sails were now carried away and at 10-15 A.M. the vessel began to put her starboard rail under the water. From this time the barometer fell with wonderful rapidity. At 11-30 A.M. (barometer at 28·95″) it was blowing a most furious hurricane and the sea commenced to make a breach over the vessel and to lay her over considerably so that it was necessary to cut away the main mast. At noon the barometer had fallen to 27·88″, and the brig was entirely at the mercy of the storm and drifting to leeward. At 1 P.M. there was quite a sudden lull, which lasted for 45 minutes.

At 1-15 P.M. there was almost a dead calm, the clouds cleared away, and the sun was faintly visible for a short time. The barometer had now fallen to 27·58″. At 1-45 P.M. the hurricane suddenly burst upon the vessel from west-south-west with more furious force than before the calm, burying the vessel under water. At 2-15 P.M it was blowing a furious hurricane from west-south-west. The seas breaking on board in succession buried her port side in the water and nearly washed overboard all the seamen who were on the quarter-deck. The wind blew away the remains of the quarter-boat, and shortly after lifted the large boat from the top of the sheep-pen, tore it away from the gripes and extra lashings, and blew it away clear off the lee rail into the sea. From 2-30 to 4 P.M. it continued to blow a furious hurricane, the vessel being under no control, but drifting with the wind. At 4 P.M. the barometer had risen to 28·68″, and the weather began to improve.

The floating light-vessels the *Mermaid*, *Planet* and *Meteor* were never nearer than about 30 miles from the centre. They experienced furious winds. Thus, the log of the *Mermaid* states that at 10-30 A.M. it was blowing a furious hurricane, the vessel driving and the rollers making a clear breach over the vessel, and at 3 P.M. it blew a terrific cyclone, with a frightful sea. Barometer 29·04″ (the lowest reading). The ship *Mistley Hall* was anchored in Saugor Roads on the 14th, waiting for a tug to take her up the river. The following are brief extracts from her log:—*15th*,—10 A.M., wind strong, east-north-east; barometer 29·59″. *Noon*, strong gale and hard squalls. 1 P.M., wind east, hard gale with tremendous gusts and torrents of rain. 2 P.M., gale increasing, barometer 29·35″. 3 P.M., wind east-south-east, hurricane with tremendous gusts and high seas breaking over us from stem to stern. 4 P.M., hurricane increasing from the south-east with tremendous gusts. 5 P.M., wind south-south-east, blowing very hard; barometer 29·05″, the lowest point reached. 6 P.M., terrific gusts, wind south: it was almost impossible to get along the decks. 7 P.M., gusts harder than ever; wind south by west. 8 P.M., hurricane continuing in a most extraordinary manner. 9 P.M., wind and weather moderating."

These extracts sufficiently illustrate the fury of the storm and the helplessness of mariners and ships when involved in the inner storm area of such a cyclone as the Midnapore cyclone.

The storm centre struck the coast near Contai shortly after 5 P.M., and then began to move first to north, then to north-north-east, and finally to north-east. It reached the coast just before the hour of low tide at the mouth of the Hooghly. The storm wave due to this cyclone hence only inundated a small portion of the Contai subdivision. The water at Diamond Harbour at 7 P.M. of the 15th, or about an hour before low water, was 16 feet above the level at the same hour of the preceding day and, about 3 feet above the previous high tide. The effects of the storm wave were hence minimized to the greatest extent by the coincidence of the time of its arrival with the lowest state of the tide.

October 16th.—To complete the history of the cyclone the following brief account of its march through Bengal is given. The centre passed near Midnapore very shortly after midnight (0-30 A.M. of the 16th). The wind increased from early morning of the 15th, when a light north-east by east wind was blowing. At 4 P.M. strong winds from north-east by north with heavy rain set in.

At 6 P.M. it blew a gale from north. At 9 P.M. the wind was sweeping over the station in furious gusts, with torrents of rain. From 9 to 12 P.M. the force of the wind continued to increase, and the wind shifted slowly from north to north-west. At 1-30 A.M. it veered towards the west, and began to diminish rapidly in intensity, and the rain ceased shortly before daybreak of the 16th, at which time a moderately high wind was blowing from the west. During the storm ten inches of rain fell. The most remarkable feature of the storm in the Balasore and Midnapore districts was the abruptness of the line of demarcation between the violent and destructive part of the hurricane, and of the moderate gale or outer storm area. The width of this western belt of destructive winds from the centre was about 25 miles, and it was near the western edge of this that the greatest destruction of life and property occurred. The loss of human life in the Midnapore district alone was 3,049, and of cattle 17,565, and was mainly due to falling trees, falling houses, or, in the case of many women and children to their being blown away and life beaten out of them by the fury of the winds. Others were blown into tanks and drowned.

After leaving Midnapore the storm centre advanced in a north-north-east direction and passed over Burdwan at 5-30 A.M of the 16th. At that station the wind on the night of the 15th was from north-east, and became more and more gusty. At 1 A.M. of the 16th it was blowing with considerable violence and at 3 A.M. the hurricane had reached its maximum strength. It blew with the utmost violence until between 5-30 and 6 A.M., when it decreased to a calm, which lasted until 6-30 A.M., when the wind recommenced to blow from the west, with gradually increasing force but with less violence than before the lull. The lowest reading of the barometer (corrected) was 28·44" at 5-51 A.M. This was nearly an inch higher than the lowest reading on board the *Coleroon*, and hence it is evident that the depression was filling up rapidly and the storm decreasing in violence. In the passage of the storm through the Burdwan district the winds were most violent, and the destruction of life and property greatest in the western quadrant, and near the outer western edge of the inner storm area, as we have seen was the case also in the Midnapore district.

The storm passed next through the Moorshedabad district in a north-easterly direction. The centre passed over Berhampore at about 2 P.M. of the 16th, or nine hours later than when it passed over Burdwan. The following gives briefly the observations at that station :—

"7-30 A.M., barometer 29·53"; north-east gale. 8-30 A.M., terrific gusts from north-east and north; 9-30 A.M., terrible gusts from north-east; noon to 1 P.M., hurricane from east and south-east; 1-15 P.M., calm; 1-30 P.M., barometer 28·98", fine calm weather with sunshine; 2-15 P.M., clouds gathering; 3-15 P.M., blowing strong from north-west; 5 P.M., weather moderating."

October 17th.—A large number of observations of various kinds from villages in North Bengal serve to show that the storm was now becoming exhausted and losing its true cyclonic character and probably breaking up into a number of separate eddies. The disturbance continued to advance in a north-east direction through North Bengal, but became more irregular and feeble, and

finally died away as it approached the western scarp of the Garo Hills on the early morning of the 17th.

As already stated, there was no destructive storm wave connected with this storm. The loss of life and property which occurred was due entirely to the violence of the winds; 3 392 human beings are reported to have perished in the storm, chiefly in the Midnapore district, but it was believed by the district officers at the time that this was far below the real estimate.

Brief summary of chief facts of storm.—The following give the most important facts connected with the storm. It formed rapidly on the 12th and 13th, after a period of squally weather apparently lasting from the 1st to the 12th, in Lat. 15° 30′ N. and Long. 90° E., and advanced to the north-north-west by an approximately straight course. It reached the Bengal coast near Contai on the afternoon of the 14th, and then curved to north, and afterwards to north-north-east and north-east, passing into North-East Bengal, where it filled up on the evening of the 16th and early morning of the 17th.

Its path and velocity at different times are given in the folowing statement:—

Date.	Hour.	Position of Centre.		Velocity during interval since previous position.
13th	Noon	16° 40′ N. Lat.	90° E. Long.	7 miles per hour.
14th	"	18° 50′ N.	88° 45′ E.	
15th	1 P.M.	21° N.	87°45′ E.	7 " "
16th	0-30 A.M.	Midnapore		9 " "
"	6 A.M.	Burdwan		10¼ " "
"	2 P.M.	Berhampore		12 " "

A remarkable feature about the storm was the very slow rate at which it advanced during its northward march up the Bay, *viz.* only 7 miles per hour.

The velocity increased, as is frequently the case, after it reached land, but it was throughout a slow-moving storm.

In both respects it resembled the still more remarkable False Point cyclone of September 1885.

The following gives the height of the barometer in the central calm area at different hours during the storm:—

Date.	Position of calm centre.	Reading of Barometer.	Observation where recorded.
14th	18° 50′N. 88° 45′E.	29·45″	On board the *Fussel Kureem.*
15th, 9 A.M.	20°45′N. 87° 55′E.	28·15″	On board the Ship *Patrie* in the calm centre.
10 A.M.		27·90″	On board the P. V. *Cassandra* in the calm centre.
1-15 P.M.	21° 0′N. 87° 45′E.	27·58″	On board the P. V. *Coleroon* in the calm centre.
16th, 5-51 A.M.	Burdwan	28·44″	At Burdwan observatory in the calm centre.
1-15 P.M.	Berhampore	28·97″	At Berhampore observatory in the calm centre.

These observations are very interesting as showing how rapidly the depression at the centre increased until it approached land, and how it filled up with almost equal rapidity after it reached land.

The following table gives a statement of the angle between the wind directions and the bearing of the storm centre for all the cases where the positions are known and the observations can be accepted as probably correct:—

Observation recorded.	Date.	Approximate distance from centre.	Approximate bearing of centre.	Wind direction.	Angle between wind and bearing of centre or bearing angle.	Weather.
		Miles.				
Saugor Island .	14th, 10 A.M. .	200	S.-S.-E.	N.-E.	112°	
	4 P.M. .	180	S. by E.	N.-E.	124°	
	10 P.M. .	145	S. by E.	N.-E.	124°	
	15th, 4 A.M. .	110	S.	N.-E.	135°	
	10 A.M. .	75	S.	N.-E.	135°	
	1 P.M. .	50	S.-S.-W.	E.	112°	
False Point .	14th, 10 A.M. .	180	S.-E.	N-E.	90°	Strong wind.
	4 P.M. .	140	S-E. by E.	N.-N.-E.	101°	Ditto.
	10 P.M. .	110	E-S.-E.	N.-E.	68°	Ditto.
	15th, 4 A.M. .	85	E. by S.	N.-N.-W.	124°	Gale.
	10 A.M. .	70	E. by N.	N.-W.	124°	Do.
	4 P.M. .	100	N.-E.	W.	135°	Strong wind.
Ireshope .	14th, noon .	135	S.-S.-E.	N.-E.	112°	Position doubtful. Heavy rain and squalls.
Udston . .	,, ,, .	100	W.-S.-W.	E.-S.-E. (doubtful)	135°	Terrific squalls
Coleroon .	,, ,, .	130	S. by E.	N.-E.	124°	Fresh breeze, cloudy, squally.
Comet .	,, ,, .	150	S.	N.-E.	135°	Squally; strong breeze.
Meteor . .	,, 4 P.M. .	140	S.	E.-N.-E.	112°	Strong breeze.
Cassandra .	,, 8 P.M. .	120	S.	N.-E.	135°	Strong wind.

The preceding table gives a large series of results for determining the bearing of the centre with respect to the wind. As already stated, the angle is that between the direction from which the wind is coming and the direction or bearing of the centre.

The Saugor Island series are very consistent, and show that the mean angle was very nearly 124°, or eleven points exactly. As the wind is measured to sixteen points, exact accuracy of angular measuring cannot be expected.

The wind observations of the vessels show a wide range of angle as might be expected, but give almost the same angle on the average (119°) as the Saugor Island measurements.

The False Point observations are very remarkable. They show that in the earlier stages of the storm the wind was fairly steady at north-east and that the bearing angle, that is, the angle between the direction from which the wind comes and the bearing of the centre, was at that time very small, averaging for

the three observations 86°, or about 8 points—but with the shift of wind to north-west, and its increase to a gale, the angle rapidly increased to its normal value 128°.

This behaviour of the north-east winds at False Point on the outskirts of a storm is not peculiar to that station, but extends over a portion of the north-west angle of the Bay. The following extract from a letter sent by Master Pilot Mr. Elson to the Bengal Meteorological Reporter, describing the cyclonic storm of September 15th, 1888, states the fact from the standpoint of a practical man:—

"When on the evening of the 14th instant, we, at the pilot station, learnt from Mr. Hills, pilot of an outward steamer, that you had hoisted No. I storm signal at the station, I must confess that I, in common with all the others present, felt some astonishment, seeing that the barometer was high, there was no S.-E. or Southerly swell, and that the wind was but light; but after dark, vivid lightning to the S.-E. told the tale that you had good data to go upon; and I, for one, well knew that your hoisting of the storm signals was a sure sign of something more wide-spread, and heavier than our limited range of vision led us to suppose. Certainly the sky was overcast more or less for two days with towering cumulus which had overspreading pallium, from which occasionally rain fell here and there, and which showed a stillness in the upper air strata, but it was not until 2 P.M. of the 15th when the wind had shifted out of the N.-W. quadrant and settled at N.-E., that I saw we were surely in for what you had so well prepared the vessels at Saugor, Nor was there any swell from seaward until well on in the afternoon, when there was no doubt about the wisdom of your hoisting the signals. So that on the whole the onset of this storm was much the same, both 'alow and aloft' as was that one which proved so very disastrous at False Point three years ago, and which I took stock of from the position of the pilot station, Sandheads, and where we (in this same brig) remained at anchor until we parted in the S.-E. turn of the winds, and I have no doubt had we in this last instance remained at anchor so as to have allowed the storm to make progress (a rather risky thing to do), I should have seen the same towering clouds above the thin stratum of turmoil below, as I observed was the case in the former storm at the hour when it was blowing a hurricane at False Point only 90 miles away. In fact, at the time when we were of necessity compelled to slip our cable and began our drift in the rapidly increasing inset of the sea current, there were some indications of this breeze being confined only to a thin surface sheet such as I saw on the former occasion, but we, in this last instance, got very rapidly away to the S.-W., closing with the centre all the while, and, consequently, the sky soon became quickly overcast and dark, with heavy rack and driving rain.

"In this breeze *there was the same prolonged stay of the wind at N.-E.* that I have observed in the whole of these storms before it veered or hauled one way or the other, so as to furnish some clue as to which side of the storm path we were on. It would doubtless be very interesting to know the reason of this persistence of the winds in cyclones hanging thus at N.-E. in and off the Hooghly, but so it is, and up to the last I was in hopes the wind would go round 'north about,' and so give us a better chance of getting the wind on starboard beam and of escaping trouble and damage, and this hope was all the more strengthened by the report of a steamer, the *Culna*, which we supplied with a pilot before noon of the 15th, which stated that on her way up from Moulmein she had experienced N.-W. squalls, and also by the report of the P. and O. steamer, which we supplied with a pilot just as the storm was bursting upon us from N.-N.-E., that she had had fine weather up along the Coromandel Coast.

"I have never experienced a heavier sea than what we had off False Point, and when closing rapidly in on the centre, probably owing to the strong current which must have been running almost dead against the wind about there setting out of False Point Bay.

"As in the last heavy False Point cyclone the rear wind of this one never went to the westward of south at all with us in the N.-W. angle of the Bay, but remained persistently at S.-S.-E. and S.-E. by S., so that on the whole the characteristics of the several phenomena of both much resembled each other, excepting that the 1885 storm was more intense."

The subject has to a certain extent been dealt with in pages 77 to 81, and its consequences pointed out. A further examination of the point after additional evidence has been obtained is very desirable. There appears, however, to be little doubt that the north-east wind is the normal wind in the latter part of September, and that it is in the early stages of the approach of a cyclonic storm very little affected for some time, especially as the winds of indraught in the outskirts of the advancing storm are modified considerably by friction with the land, and it is only when the increased force due to the continued advance of the storm accumulates sufficiently that the shift of wind from north-east takes place rapidly, and then for the first time indicates approximately the bearing of the centre.

As to the fact and its practical bearing there can be no doubt. The north-east winds in the outskirts of cyclonic storms advancing to the north-west angle of the Bay are peculiarly treacherous and misleading. The fact, it may be added, furnishes a strong argument for the establishment of telegraphic communication to the light-vessels at the entrance of the Hooghly, if it be possible to effect it.

The False Point Cyclone of September 19th to 23rd, 1885.

The False Point cyclone of 1885 is a very remarkable example of the small, but very intense and severe, cyclones which occasionally occur in the Bay. The lowest barometric reading (27·135″) taken at the False Point Light-house during the passage of the storm centre over it is lower than any previously recorded verified barometric reading at the sea-level. It was, moreover, taken by a trained observer with a properly verified barometer at a land observatory, and may hence be accepted as quite accurate. The cyclone was in character a storm of the transition period—October to December—rather than of the rains. It however occurred at least a fortnight earlier than any storm of similar intensity has been previously recorded, and is therefore in several respects unique.

Weather previous to the storm.—The storm began to form, so far as can be judged from the reports, on the afternoon of the 18th of September or the morning of the 19th. The weather for some days previously in Bengal and Northern India was such as accompanies a partial break of the rains. Rain practically ceased to fall in Upper India, skies cleared and winds became variable in direction and unsteady, and indicated by their feebleness and irregularity of direction that they were no longer part of the general air movement of the south-west monsoon current proper. They were in fact very light local breezes or airs in an area beyond the limit for the time being of that circulation. This change of conditions gradually extended eastwards. Very little rain fell in South Behar and Chutia Nagpore for some days after the 9th or 10th. Rain continued to fall locally in the neighbourhood of the hills in North Behar and in Bengal. A very small depression or whirl formed near the head of the Bay on the evening of the 14th, and advanced in a north-westerly direction and crossed the coast near Saugor Island on the afternoon of the 15th. It however filled up during the next 24 hours, and the weather over the whole of Bengal and Northern India on the morning of the 16th, was such as is characteristic of a break of the rains.

Pressure was very uniform over the whole of Northern and Central India on the morning of the 16th. It was slightly higher in Arracan and South Pegu and at the Andamans, and hence probably over the adjacent Bay area. It was also considerably above the average pressure of the period, a condition which frequently holds before the commencement of cyclonic storms in September and October in the Bay, as for example the Calcutta and Midnapore cyclones. Winds were light, unsteady and variable in Northern India. They were from the south-west in South Bengal, but further inland they were local, and very variable and irregular, so that it is not possible to assign any average general direction of the air movement in Northern India at this time. Behar, however, separated an area to the east, including North and Central Bengal in which southerly to easterly winds prevailed, from an area to the west, including the North-West Provinces and the Punjab, in which light local westerly airs generally prevailed. No rain fell in Upper India, and practically none (that is, only a few local showers of no importance) in Behar and Chutia Nagpur. Moderate rain fell in Bengal, giving an average for the 24 hours preceding 6 P.M. of the 16th of about one-third of an inch. The weather during the next four or five days does not require detailed description. It is sufficient to note that the skies cleared almost entirely in Behar, Assam and Bengal; the south-easterly or easterly winds which had hitherto prevailed not only decreased in force, but were replaced over the whole of Bengal, except near the sea coast, by local breezes which were in many cases from opposite quarters at neighbouring observatories. The weather was fine, with occasional passing clouds. Temperature increased to some extent and the weather became, as is always the case during a break in the rains in September, sultry and oppressive. The barometer varied slightly from day to day, rising and falling in response to the general slight atmospheric movements which appear to affect the whole of India almost simultaneously, and which have no reference to local phenomena such as, in the present case, the formation of a fierce cyclonic storm.

We have now to consider the character of the weather in the Bay previously to the formation of the cyclone, so far as it can be illustrated from the meteorological information contained in the logs of ships. The weather in the Bay on the 16th appears to have been such as always obtains when the south-west monsoon is feeble. Pressure was lowest in the north of the Bay, and highest in the south, but the differences or gradients were small in amount. Light west to south-west winds prevailed over its whole extent. The *Cuthona*, *Calcutta*, *Cynosure*, *Kunt Alfsson*, *Rollo*, *Blairgowrie*, *Saint Marnock*, *Goa*, and *Minnyhive* were all at or near the entrance to the Bay, and between Lat. 1° S. and 7° N. and in Longitude varying from 82° to 99° E. at noon. They all experienced light winds, in no case exceeding 4 in force. The logs of the majority of those vessels record that the weather was clear and fine. Three report showers of rain, with slight squalls. Further north, the *Britannia* in Lat. 10° 19′ N. and Long. 86° 58′ E. had fine weather throughout the day, the *Brindisi* in Lat. 17° 49′ N. and Long. 84° 37′ E. had winds somewhat variable in direction and varying in force from light airs to a moderate breeze. The ship *Governor Wilmot* rounding the Alguada at noon had fine clear weather, smooth sea and light variable airs during the morning and afternoon, and a "very fine-

looking sky" at 8 P.M. The *Lactura* near the head of the Bay had clear weather with passing clouds. The information is by no means complete, but, so far as it goes, it indicates strongly that the weather was fine in every part of the Bay, and that light monsoon winds generally prevailed. There was in fact not a single indication as yet of the commencement of squally weather, such as always precedes the formation of a cyclone.

September 17th.—The ship and land observations of the morning of the 17th show no change in the distribution of pressure over the greater part of the Bay. There was also no important change in either the wind directions or the general character of the winds and weather. There were, however, as experienced by two or three ships, slight signs of the commencement of squally weather. The *Minnyhive, Saint Marnock, Blairgowrie* and *Cuthona,* which were between Lat. 1° N. and 4° N. at the entrance of the Bay, had hot, sultry weather in the morning, and sharp squalls with heavy rain in the afternoon and evening. Further north the *Rollo* in Lat. 6° 46′ N. and Long. 87° 52′ E. and the *Cynosure* in Lat. 8° 09′ N. and Long. 87° 40′ E. and the *Kunt Alfsson* in Lat. 9° 49′ N. and Long. 85° 02′ E. had strong steady south-west winds during the day, with fine weather. These moderate to strong south-west breezes appear to have extended northwards as far as Lat. 13° or 14° N. The *Britannia* in Lat. 13° 02′ N. and Long. 87° 8′ E. had south-west winds of force 4 and fine fresh cloudy weather. Further north different weather prevailed. For example, the captain of the steam-ship *Governor Wilmot* in Lat. 15° 29′ N. and Long. 94° E. at noon reported that it was very hot and sultry in the morning and suffocatingly hot in the afternoon. The sea was very smooth and winds very light and variable (force 1). Several vessels contribute to the meteorological information of the north of the Bay on this day. The logs of these vessels describe the weather in such terms as "moderate breeze and fine." "Fresh breeze, small clouds, fine weather," "fine clear weather, with fresh breeze," "weather fine and clear, sea smooth throughout." These observations for the 17th hence show clearly the character of the weather at this time. Moderate monsoon winds prevailed as far north as about Lat. 14° N. In this area weather was fine, although there were signs of the commencement of squally weather in the extreme south of the Bay. To the north of Lat. 14° N. light variable winds and hot, sultry oppressive weather prevailed.

September 18th.—The observations of the next day (18th) show that during the preceding interval of 24 hours a slight fall of the barometer had occurred over the whole of India (nowhere exceeding a tenth of an inch), but there were as yet no indications of the formation of an area of slight local depression in the Bay. Over the greater part of the Bay there was no perceptible change in the weather. The south-west monsoon winds at and near the entrance of the Bay were increasing in strength and giving rise to frequent and stronger squalls. The *Saint Marnock* had south-south-west winds, force 4 to 6, and squally weather with heavy rain in Lat. 4° 26′ N. and Long. 84° 19′ E. The *Minnyhive* in Lat. 3° 37′ N. and Long. 88° 26 E. had hard squalls during the day, and the sky had a dirty, wild-looking appearance. The *Rollo* in Lat. 10° N. and the *Cynosure* in Lat. 11° 30′ N. had strong steady west-south-west winds. The *Britannia* in Lat. 15° 50′ N. and Long. 87°3′ E. had south-west winds of force 5 and much

lightning with heavy showers. The ship *Governor Wilmot*, in Lat 15° 37′ N. and Long. 93° 20′ E. had light variable and very unsteady winds both in force and direction, and very hot, sultry and oppressive weather. A heavy bank of clouds was also observed during the afternoon and evening to the north-east.

The logs of a large number of vessels show that in the north ot the Bay fine clear weather, with light south-westerly winds (but somewhat unsteady in character) still prevailed. The only part of the Bay area for which the information is somewhat scanty and imperfect is the Andaman Sea. The observations at Port Blair and Nancowry, and at the Burma and Tenasserim coast stations, as well as those taken on board ships in the Bay, shew most clearly that there was no cyclonic motion of the air in that part of the Bay. Squally weather with frequent heavy rain-showers prevailed over a large portion of the south and centre of the Bay, and the disturbed weather was extending northwards and invading the area of light variable winds and hot sultry weather to the west of the Pegu coast, so that a heavy bank of clouds had collected or formed apparently in the area over which the storm began to form during the next 24 hours. The observations at the Bay Islands confirm these statements to some extent. Thus, at Port Blair heavy rain was falling, skies were gloomy, and winds had increased very considerably in force. They were blowing from west or south-west, and were hence normal in direction, and such as precede and accompany the formation of a cyclone to the west of the Andamans, and not to the east. Moderate rain had also fallen at Nancowry. Little or no rain was falling in Burma.

The observations hence show that a considerable increase in the strength of the south-west monsoon winds had occurred over the south of the Bay. This was apparently due to an advance northwards of strong humid winds from the neighbourhood of the equator, as the general conditions in the north of the Bay remained unchanged. Weather also became unsettled and squally, and heavy rain *began to* fall in some parts of the south and centre of the Bay. So far as can be judged, this rainfall was heaviest at and near Port Blair, and it was in the sea area to the north of the Andamans that the cyclonic storm originated and was generated during the next 24 hours.

Account of the storm.—*19th September.*—No change of importance occurred during the 24 hours preceding 10 A.M. of the 19th in Bengal or over the Bay north of Lat. 18° N. Calms or variable airs continued. A slight further fall of the barometer had taken place, but was apparently only a continuation of the same general movement as on the previous day.

The weather in the Bay on the 19th is fully illustrated by the meteorological information extracted from the logs of the vessels. In the south of the Bay the south-west air current continued to increase in volume and intensity, and its northward advance over that area to the centre of the Bay (more especially the eastern half) was now accompanied with very unsettled, squally weather. The S.S. *Minnyhive* in Lat. 6° 38′ N. and Long. 89° 12′ E. had westerly winds, and the captain states there was every indication of bad weather to the northward, the most significant of which were dense heavy clouds from north-west to north-east above the horizon and frequent lightning. The S.S. *Cuthona* in

Lat. 10° N. and Long. 88° E. had moderate west-south-west winds, force 4. There was a bank of clouds to the north and frequent lightning. At sunset the sky was very red. The *Blairgowrie* in Lat. 9° 18′ N. and Long. 87° 26′ E. had south-west winds of force 6 and a fresh monsoon. Skies were dull and heavy, and there was much lightning to the north and north-east. Three vessels, the *Rollo, Cynosure*, and *Calcutta*, were all in about Long. 88° E., and between 12° and 14° N. Lat. All had west to west-south-west fresh breezes, and fine and hot weather. The only vessel near and within the area in which the storm was forming on this day was the ship *Governor Wilmot.* Her account shows the inception and increase of the storm during the day. She was in Lat. 14° 27′ N. and Long. 92° 8′ E. at noon, and proceeding slowly westwards on her course from Diamond Island to Calcutta.

The following extracts, giving the weather experienced, are from her log:—"*Early morning.*—North-west winds, force 6. Squally-looking, with smooth water. Constant rain. *Morning.*—Increasing breeze, with constant heavy rain. *Noon.*—Wind very unsteady; constant rain. Very heavy rain at 4 P.M. Wind increased at 8 P.M. to force 8 from the west, and blew a whole gale."

The above account agrees with the general experience of cyclone generation in the Bay. Heavy continuous local rain in an area of light unsteady winds, fed by strong south-west monsoon winds prevailing to the south, is always the chief and most prominent feature. The barometer usually commences to fall simultaneously with the heavy rainfall. Winds are for some time afterwards unsteady, although increasing in force, and are interrupted by squalls, which increase in frequency and in intensity. After some time regular cyclonic motion of the air is established, which, if the rainfall continues and increases in amount, develops into rapid and violent cyclonic motion on the large scale over the storm area. This change in the present storm appears hence to have gone on continuously on the 19th in a small portion of the Bay to the south-south-west of Diamond Island, and north of the Andamans, and on the afternoon and evening of the 19th the cyclonic storm was fully initiated. The observations taken at Diamond Island, about 170 miles to the north-east of the *Governor Wilmot's* position at noon, fully confirm the above, and show that the wind velocity there increased between 10 A.M. of the 18th from 10 miles an hour to an average of 25 miles an hour on the 19th and 20th. The storm was only in its initial stage on the evening of the 19th. It however gained very rapidly in intensity, and commenced to move slowly to the north-west in an almost straight course across the north of the Bay to False Point.

20th September.—The land observations in Northern India on the 20th give no marked indication of the existence of the storm in the Bay. The barometric changes were generally small and variable in amount. Fine clear weather prevailed in Upper India. Winds were extremely light in Bengal, but southerly winds continued to prevail on the Bengal and Orissa coasts. Skies were partially clouded, as is generally the case in September, but very little rain fell.

The logs of the ships furnish abundant evidence of the unusually rapid growth of the storm. They show that the centre at noon of the 20th was in Lat. 15° 30′ N. and Long. 91° 30′ E. or Long. 92° E. There were a large number of vessels

to the south and west of the centre during the day. Their logs all record that unsettled squally weather, with gloomy threatening skies, extended over the greater part of the Bay south of 18° N. Lat. and east of Long. 86° E., but that strong winds (or winds exceeding 8 in force) were only experienced up to a distance of 60 or 80 miles from the centre, except in the south quadrant, where they extended over a large portion of the south of the Bay.

The following extracts from the logs of the three vessels nearest to the storm centre during the day will sufficiently illustrate its growth. The *Governor Wilmot* was nearest to the centre in the morning and at a distance of 60 miles to the north-north-east at noon. Her log for the day is as follows :—"4 A.M.—Wind west-north-west, force 10. 8 A.M.—Wind west, force 11, blowing a hurricane. Sky black, with thick low clouds; constant heavy rain. Barometer fell rapidly during the morning and stood at noon at 29·5". The sky was very thick and black at noon, so that it was more like night than day. 4 P.M.—Wind south-west, force 11. 6 P.M.—Weather began to improve." The changes are evidently explicable by the rapid growth of the storm, and its north-westerly advance away from the vessel.

The *Cynosure* was about 180 miles to the west by south at noon. She had, at 8 A.M., moderate breezes and cloudy skies; at noon light airs and calms, thunder and lightning; and in the afternoon squalls and heavy rain.

The *Canara*, about 200 miles to the north-north-west at noon, and advancing to Calcutta, describes the weather as follows :—

"4 A.M.—Wind east-north-east, force 5; fresh breeze and cloudy; squally, moderate sea. *Noon.*—Fine clear weather. 8 P.M. to midnight.—Moderate breeze. Passing clouds, smooth sea."

These observations prove conclusively that the storm area of this cyclone was of small extent, and that outside this storm area the winds and sea were very slightly influenced as yet by the disturbance.

September 21st.—The various observations indicate that the centre at 10 A.M. of the 21st was in Lat. 17° 30′ N. and Long. 89° 30′ E. or 89° 45′ E., so that it had travelled 180 miles to the north-west during the previous 24 hours. No important change had occurred in the weather in Upper India. In Bengal skies were much less clouded than they had been previously.

The storm moved more rapidly during the afternoon and night of the 21st, and reached the Orissa coast early on the morning of the 22nd. It apparently grew rapidly in intensity during the day, but the inner storm-area was not much enlarged, so that it continued to present the same features as on the 20th of a small area of not more than 50 or 60 miles in diameter in which the winds raged with hurricane force, whilst beyond it they decreased rapidly in intensity, and at distances of 80 to 100 miles from the storm centre were comparatively feeble.

The following gives extracts from the logs of those ships which were involved in the storm during the 21st. The first was the *Calcutta*, which was about 50 miles to the south of the centre at noon of the 21st. The account in her log is brief:—" Winds changed gradually from north-west to west by south, and then to south-south-west, and finally to south by east. Terrific squalls at noon

with a regular downpour of rain. The sea in the evening seemed to come from all quarters." This vessel passed from the south-west to the southern quadrant, but was never nearer the centre than about 50 miles.

The schooner *Kunt Alfsson* was also on the outer verge of the inner storm area during the morning and afternoon, and in the same quadrants (*i.e.* western and southern) as the previous vessel. Her log states:—"Early morning, it was calm until 3 A.M., when the wind began to blow from north, and afterwards shifted to north-west. It freshened to a stiff breeze with squalls and rain before noon. During the afternoon the wind became stronger from north-west, with frequent squalls and an immense quantity of rain. Before 4 P.M. the wind was blowing a terrific gale. At 4 P.M. wind was from west, and at 7 P.M. from west-south-west. The water was discoloured and appeared to be black. We sounded, but obtained no bottom, with 90 fathoms. Rain poured down continually during the afternoon in immense quantities without ceasing. The gale blew in terrific gusts, and the sky was intensely black, the sea very turbulent and high." The log does not indicate at what time she was nearest to the centre nor the height of the barometer, and hence the remarks are chiefly valuable as evidence of the excessive condensation of aqueous vapour and precipitation of rain which was the chief cause of the concentration and violence of the storm.

The *Quang Tung* left the Sandheads on the 19th for the Andaman Islands, and her course took her directly through the storm area. She was nearest to the centre at 4 P.M. of the 21st, when she was about 70 or 80 miles to the north of the centre and in the outer storm-area. The following extracts are from her log of that day:—

"4 A.M.—Sea smooth. 8 A.M.—Wind east-north-east, force 5. Moderate north-east sea and swell. 9-45 A.M.—Wind and sea rapidly increasing. Very heavy south-east sea. *Noon.*—Wind east by south, force 8. Very heavy sea. 4 P.M.—Wind east by south, force 9. 8 P.M.—Very hard squalls from the eastward."

The next vessel in order of time was the *Clan Mackintosh.* She was proceeding northwards to the mouth of the Hooghly, and was, hence, advancing across the line of march of the storm during the day. The following account is taken from her log:—

"*September 21st*, 4. A.M.—Light variable winds; sea smooth. 8. A.M.—Freshening breeze, with dark gloomy weather. 8-30 A.M.—Violent squalls and heavy rain. *Noon.*—Strong breeze (north) with heavy squalls of wind and rain. *Afternoon.*—Wind (north) increased. Ran to south-west to avoid cyclone. 10 P.M.—Wind shifted to north-north-west. *Midnight.*—Strong gale, with terrific squalls and torrents of rain. Wind blowing at times with hurricane force. Wild confused sea. *September 22nd* 2 A.M.—Barometer 29·60 (lowest). Wind north-west, blowing at times with hurricane force. Torrents of rain; vivid lightning. 5 A.M.—Wind moderating and sea less confused. 5-50 A.M.—Turned ship's head round and set course N. 24°E."

September 22nd.—The tug steamer *Britannia* was advancing slowly to the mouth of the Hooghly and was off the Orissa coast on the 21st. She was hence

right in the track of the cyclone and experienced its full weight on the night of the 21st. The following account is extracted from her log:—

"*21st* 4 A.M.—Wind east-north-east, force 3. *Noon.*—Barometer 29·6", wind north-north-east, force 6. 4 P.M.—Barometer 29·5," wind north-east, force 6. From noon the wind increased in force, and at 1 A.M. of the 22nd was blowing with hurricane force. Barometer stood at 28·2" (corrected reading 28·16") from 1 A.M. to 3 A.M., when there was half an hour of calm weather. The wind then came down from the west (backing to south-west) with terrible force until 6 A.M., when it began to moderate. During the storm the fore and main top-gallant masts and yards were lost, and the whole suit of sails blown away from the yards, except the main sail and jib.

The *Booldana* on the 21st was lying off False Point at the anchorage ground. At 4 P.M. wind was from east-north-east, when there was a heavy sea running and dirty squally weather. At 8 P.M. wind north-east, force 9. Sea increasing. At midnight strong gale, with *very hard dry* squalls. 2 A.M. of the 22nd.—Gale increasing with slight rain. 3-30 A.M.—Heavy squall; wind blowing a very heavy gale. 4 A.M.—Barometer began to fall very rapidly, and wind and rain increased. 5 A.M.—Wind north-east. 6-15 A.M.—The weather cleared up with clear sky overhead, but round the horizon all dark. 7 A.M.—Barometer at its lowest 27·4" (uncorrected). The gale came down from the opposite quarter (south-west), making it impossible to stand on deck without holding on. 9 A.M.—Barometer 29·2". 9-45 A.M.—Force of the gale gradually abated. *Noon.*—Fresh squalls from south-west.

The weather in other parts of the Bay was more or less squally with strongish winds and a high sea. The sea was specially high in the shallow water at the head of the Bay. The following brief quotations will suffice to describe it:—

The *Favonius* in Lat. 16° N. and Long. 85½° E. at noon had very high seas and very cloudy weather. The sea was running from all directions. The ship *Governor Wilmot* in Lat. 17° 40′ N. and Long. 90° E. at noon had an awful sea from north-west at 4 P.M. The barque *Rollo* in Lat. 18° 17′ N. and Long. 89° E. had a high confused sea, and a strong gale and rain. The pilot vessel *Coleroon* was at anchor at the Sandheads. Her chains parted at 6-30 A.M. of the 22nd, owing to the tremendous sea running.

The lighthouse at False Point is situated about 7 miles to the south south-west of the anchorage ground in the harbour. The calm area passed over it very shortly after it reached the *Booldana*. The following is the account of the weather, as given by the lighthouse-keeper:—"The weather began to assume a threatening appearance between 4 and 5 P.M. of the 21st, when the wind was from the north-east, and blowing in squalls with an overcast sky, and heavy banks of clouds rolling up from the north-east. The weather continued the same, with the wind increasing in force and squalls, more frequent until between 1 and 2 A.M. of the 22nd, when it blew a gale. At 4 A.M. the wind had increased to a hurricane, and the squalls were most terrific, with blinding sheets of rain. The wind was still from the north-east, and the barometer falling rapidly. At 6-30 A.M. the wind hauled to the north-west, and continued

to blow a hurricane for a few minutes, when it suddenly lulled and became almost calm. At 6-50 A.M. the wind came down with redoubled force from the west-south-west, the gusts being most terrific. From 7 A.M. to 10 A.M. the barometer rose rapidly and the wind gradually moderated to a gale, and at noon it blew a fresh breeze from the south-west, with squalls."

The storm advanced in a north-westerly direction during the day across North Orissa and Chutia Nagpore, and gave very heavy rain in Orissa. The Collector of Balasore reported that the rainfall on the Orissa hills was extraordinarily heavy, and caused high floods in all the rivers in his district, which inundated all the low-lying lands. Strong southerly winds continued over the whole of the centre and north of the Bay during the day. Thus, the *Blairgowrie* in about Lat. 19° N. at 4 P.M. had south-west winds of force 6, the *Favonius* in Lat. 16° N. south-west winds of force 7, the *Quang Tung* in Lat. 20° N. southerly winds of force 6. In the south of the Bay light south-west winds of force 2-4 prevailed.

September 23rd.—The centre passed through the districts of Ranchee and Hazaribagh on the early morning of the 23rd, and was between Dehree and Hazaribagh at 10 A.M. The storm had however almost filled up by this time, and it existed for some hours longer as a diffused disturbance which advanced northwards into North Behar, where it finally broke up completely on the morning of the 24th. The strongest winds in the Bay on that day were only of force 3-4, so that the weather in the Bay had reverted to its normal character at the end of September.

The storm wave.—The storm wave inundated the whole of the low land in the neighbourhood of the False Point Harbour. High water was due at about 8 A.M., so that the storm wave which accompanied the central depression and calm area preceded the tidal wave by about 2 hours. The storm wave came up at 6-20 A.M. and swept over False Point Harbour, destroying all the houses ashore. It passed over Jumbo at the entrance to the canal, and then rolled in one wide unbroken wave in a north-easterly direction over Kaldeep and Kerara, submerging villages and carrying away before it, with irresistible force, houses, cattle, human beings, &c. The trees were rendered leafless and scorched as if by the blast of a furnace. The measured height of the wave above mean sea-level was 22 feet at False Point and 21 feet at Jumbo. The effect of the tidal wave was suddenly to create a sufficient depth of water all over the harbour sufficient to float large steamers. The *Booldana* was carried over shoals where there is ordinarily at high tide only a few feet of water.

Brief summary of chief facts of storm.—The preceding account has hence shown that the False Point cyclone was generated in an area of calms and light unsteady winds to the south-west of Diamond Island on the 17th and 18th. Excessive rain fell in this area, and the storm developed with unusual rapidity on the 19th in about Lat. 15° N. and Long. 92½° E. It was fully formed on the afternoon of the 19th and marched in a north-westerly direction. The centre advanced rapidly without change of course to the Orissa coast, which it reached about 6 A.M. on the 22nd. The central calm area passed over the light-house, and lasted for half an hour. The storm advanced across Cuttack and the Orissa hlils, but decreased very rapidly from this period. It gave a deluge of rain to

those hills, and thence passed through Chutia Nagpur on the 22nd and Behar on the 23rd, and died out in North Behar on the morning of the 24th, after having given heavy rain in Chutia Nagpur and moderately heavy rain in Behar.

The following table gives the positions of the storm centre at different hours :—

Date.	Position of the centre.	Motion during previous interval.	Average rate of motion.
20th—10 A.M. . .	15° 30′ North, 91° 30′ East		
21st—10 A.M. . .	17° 30′ „ 89° 30′ „	180 miles in previous 24 hours.	7½ miles per hour.
5 P.M. . .	18 „ 88°20′ „	92 miles „ .	13 „ „
22nd—6-30 A.M., 6-50 A.M.	False Point Lighthouse	170 „ „ .	12½ „ „
23rd—10 A.M. . .	Near Dehree . .	320 „ „ .	13 „ „

Hence, during the latter part of its existence it moved very uniformly, and at a rate averaging 13 miles per hour.

The following gives the readings of the barometer in or near the storm centre at different hours :—

Date.	Position of calm centre.	Corrected barometric reading.	Where observed.
21st September, noon .	Lat. 17° 30′ N., Long. 89° 15′ E.	29·26″	On board the *Calcutta*, a little to the south of the storm centre.
„ 5 P.M. . . .	„ 18° 40′ N., „ 88° 20′ E.	28·79″	On board the *Kunt Alfsson*, a little to the south of the centre.
22nd, 3 A.M. . . .	45 miles east-south-east of False Point.	28·16″	On board the *Britannia*, 45 miles east-south-east of False Point in the calm centre.
22nd, 6-30 A.M. . .	False Point . .	27·135″	Observed at the Lighthouse during the passage of the calm centre.
23rd, 10 A.M. . .	Dehree . . .	29·543″	At observatory to the west of the centre.

These data show how rapidly the storm developed in intensity on the afternoon and night of the 21st and early morning of the 22nd. The barometric depression increased an inch at the centre (if the data, which appear to be thoroughly trustworthy, be accepted) between 3 A.M. and 6 A.M. on the early

morning of the 22nd when approaching the Orissa coast. The storm apparently filled up with equal rapidity after reaching land.

The following table gives the distances at which winds of intensity 8 and upwards were observed at sea:—

Date.	Ship.	Bearing and distance of centre.	Force.
20th, noon	Governor Wilmot	90 miles north-west	11
„ 8 P.M.	Cuthona	300 „ north-east	11
21st, 4 A.M.	Governor Wilmot	225 „ north-west	8
„ noon	Blairgowrie	110 „ north	8
„ 4 P.M.	Cuthona	250 „ north-north-east	10
„ 4 P.M.	Quang Tung	180 „ south	9
„ midnight	Brittania	260 „ south-east by south	10
22nd, 4 A.M.	Saint Marnock	340 „ north-north-west	8
„ 4 A.M.	Booldana	Near Centre	11
„ noon	Quang Tung	250 miles west-north-west	8

The relation between the bearing of the centre and the direction from which the wind was coming is given for each of those cases in which the position or the place of observation is known, and the wind observation appears to be reliable.

The following gives the angle between the direction of the wind at Saugor Island and the bearing of the centre during the storm:—

Time.	Wind direction.	Distance and bearing of centre.	Bearing angle.	Weather.
10 A.M., *21st*	N.-E. by E.	300 miles to S.-S.-E.	101°.	Squally.
2 P.M., „	E.-N.-E.	250 miles to S.-S.-E.	90°.	„
6 P.M., „	E.-N.-E.	200 miles to S. by E.	101°.	„
10 P.M., „	E.-N.-E.	155 miles to S.	112°.	„
2 A.M., *22nd*	E. by N.	130 miles to S.-S.-W.	124°.	Gale.
6 A.M. „	E. by S.	120 miles to S.-W.	124°.	Severe gale.

This gives an average of 109°, or 10 points, and shows a considerable amount of variation, *viz.* from 90° to 124°, or 34°, which is not much beyond the limits of variation that might be expected from the rough method of measurement of wind direction employed, and the position of the observatory in the north-west angle of the Bay.

The wind at False Point remained steady at north-east during the whole period of approach of this storm until within a few minutes before the calm area reached the station, when it shifted suddenly to north-west. As the storm advanced in a north-westerly direction to False Point, the angle between the wind direction and centre was hence throughout 90°. This is another example of the peculiar wind relations which appear to obtain at False Point and probably over the adjacent portion of the Bay.

The following table gives data for ships the positions of which are known to be approximately correct :—

Date.	Wind direction.	Approximate bearing and distance of centre.	Bearing angle.	Weather.
Canara, 20th, noon .	E.-N.-E. .	160 miles S. . . .	112° . .	Squally.
Blairgowrie, 21st, noon	S.-W. .	110 „ N. . . .	135° . .	Fresh gale.
Britannia „ .	N.-N.-E. .	210 „ S.-E. . .	112° . .	Gale.
Rollo „ .	N.-W.by W.	150 „ N.-E. . .	101° . .	„
Governor Wilmot .	S.-S.-W. .	230 „ N.-W. . .	112° . .	Squally.

The data give a mean angle of 114°, or very nearly ten points.

The Akyab Cyclone of May 1884.

This small cyclone is an example of a class of storms which are of almost annual occurrence. These storms are formed in the month of May, when the south-west monsoon current proper enters and advances up the Bay of Bengal.

The storms which are generated in this manner during the first fortnight of May usually advance to the Madras coast. Those which are formed in the latter part of May or beginning of June generally move north-west to the Bengal or Orissa coast, but under very exceptional circumstances they advance northwards and then recurve to north-north-east or north-east and strike the Arakan or Chittagong Coast.

The present storm, although it was generated during the first fortnight of May, marched northwards and then recurved and struck the Arakan coast. It was thus very remarkable in its chief features.

Weather conditions of month of May in India and the Bay of Bengal.— The weather in India during the month of May presents very great contrasts. In the interior of the country the air is excessively dry and the day temperature very great, the maximum ranging from 110° to 125° over the whole of the interior (except during occasional periods of thunderstorms and dust storms). Very strong winds blow down the larger river valleys and across Central India during the day, and, as they pass over the dry heated surface of the earth they are, during the latter part of the day, raised to a high temperature and form the hot winds of Upper India and the Gangetic plain, &c. The differences of pressure from one point to another over the areas in which they prevail are usually very small. In the coast districts strong sea breezes blow across the coast into the adjacent interior districts during the day. These winds in the Bay usually commence on the coasts of Bengal and Orissa in the latter part of February or beginning of March. The barometer falls rather rapidly in the Bay of Bengal as the coasts of Bengal and Orissa are approached, and also for some little distance inland. The southerly sea-winds which prevail in the coast districts, and more especially South Bengal, and in the adjacent sea area during the hot weather, extend to some distance seaward. They increase in strength as the season advances, and extend to greater distances from the coast seawards, as well as landwards. Hence southerly winds blow into Bengal and Orissa across, the coast, and, although they are mere local winds which do not extend far into the

interior or out to sea, they are of even greater average force than the south-west monsoon winds of the months of June, July and August. For example, the average daily amount of wind at Saugor Island in April is 401 miles, and in July is 350 miles; at False Point the average daily wind amount in April is 320 miles, and in July 251 miles. Over the greater part of the Bay, including the south and centre, as far north as Lat. 18° N., the weather conditions are quite different. The temperature is high, but is very much more uniform than on land; the maximum day-temperature is from 30° to 40° lower than in the interior of India, and the night temperature from 5° to 20° above that of Central India. The air near the surface of the water is very humid, and partly from this fact and from the stillness of the air and the dust carried up into the higher atmospheric strata by the strong winds in India, and brought over the Bay by the upper return currents, the air is always more or less hazy. The winds are usually exceedingly light, and calms are of frequent occurrence and last occasionally for many days. The sea is hence quite smooth, and ships passing up the Bay during this period sometimes do not make more than a few miles per diem for days together.

This, then, is the normal condition of the weather in India and the Bay of Bengal in the month of April or the beginning of May. This state of affairs usually lasts for some weeks, the intensity increasing, but being relieved at intervals (so to speak) by series of thunderstorms and nor'-westers in the coast districts (especially in Bengal and Orissa), and which frequently give very heavy rain and cool the air for two or three days. These conditions are terminated by the commencement of the south-west monsoon proper, and of the summer rains in India. According to many meteorologists the great and determining cause of the south-west monsoon is the high and increasing temperature in India. This heated earth-mass acts like a furnace, according to them, and draws in the air from all directions, and as it becomes hotter and hotter the suction increases and draws in air more rapidly and from greater distances away. The indraught or suction should, according to this explanation, commence near the furnace or heated mass, and travel or extend away from it. It should be strongest and commence at and near the hot area or furnace, and be felt at gradually increasing intervals of time further and further away from it. Hence it is that hose who adopt this explanation maintain that the south-west monsoon commences on the Bengal and Orissa coasts in the month of March, and gradually advances southwards down the Bay. This is not supported by facts. There are undoubtedly local sea-winds in and near the coast districts in March, April and May, which extend some little distance down the Bay. But beyond there is always a large area of light variable winds and calms until the beginning or middle of May, when strong winds begin to blow at the entrance to the Bay and advance sometimes slowly, sometimes with a rapid rush up the Bay (frequently giving rise to a storm), and it is only when these have covered the whole of the Bay and united with, or absorbed, the local sea-winds at the head of the Bay, that the rains proper commence in Bengal, and strong south-westerly winds prevail throughout the Bay. The impulse or rapid rush of south-west monsoon winds up the Bay suggests most strongly the action of pressure from the south on the moving mass of air rather than that of suction or indraught extending from the hot area

in Upper India down the Bay, and drawing the air up the Bay from the south. When this vast advancing humid mass of air enters and advances over the south of the Bay (where the air was previously in an almost quiescent state) forcing its way forward, there is much internal commotion. Squalls are of frequent occurrence, and rain falls in large amounts. And when these winds and squally weather have marched some little distance up the Bay, as far as Lat. 10° or 11° N., the rainfall and squalls frequently become intense, and the disturbance thus set up gradually becomes more localized and concentrated, and occasionally develops into a cyclonic storm. If these actions take place early in May, the storm so formed usually marches to the Madras coast in a west-north-west direction. The present storm is an example of this class of storms which form during the early advance of the south-west monsoon air current up the Bay. It however adopted a very unusual course, and marched first north, and then curved round to north-east and struck the Arakan coast near Akyab.

Weather previous to the formation of the cyclonic storm.—The history of the cyclone commences on the 11th of May, when the weather in the Bay was such as is described in the preceding paragraphs. South-west winds of force 3 to 4 were blowing at the head of the Bay, and the weather was fine, but hazy. To the south of 20° N. light variable winds and calms prevailed over the whole of the Bay as far south as Lat. 6° N. But over and near the Equator the weather was unsettled and squally. Skies were overcast, and heavy showers of rain were falling at intervals. The log of the ship *Belfast* of Liverpool, which had made a rapid and favourable passage through the south-east trades, and was in Lat. 5°3′ S. and Long. 87° E. at noon on the 11th, states that she had steady south-east winds until 7 P.M. of that day, when a squall from west-north-west passed over the vessel. The weather at Galle and Colombo was fine, with passing clouds, and winds were light. Hence the character of the weather in the Bay on that day is evident. Over a narrow belt near the north and west coasts there were strongish winds blowing from the sea to the land. Over the whole of the Bay proper, winds were very light and variable, weather sultry, and the sea smooth, and there was no sign or indication of stormy or squally weather.

12th May.—During the next 24 hours no change occurred except in the extreme south of the Bay.

The *Kalima*, in Lat. 3° N. and Long. 84° E., had violent south-west squalls and heavy rain. The *Udston*, 40 miles further north, had hard west north-west squalls and heavy rain. The *Bhundara*, in Lat. 8°20′ N. and Long. 82°30′ E., experienced light to moderate west-north-west winds and showery weather. Further north, from Lat. 10° N. to Lat. 18° N., light variable winds and clear fine weather continued. The *Iolanthe*, in Lat. 16° N. and Long. 93° E. at noon, had light variable winds and a slight swell from south-south-east. There were a few light detached clouds about, but with that exception skies were clear. The light-ships at the entrance to the Hooghly had fine weather and a smooth sea. Hence the only change in the weather was the advance of squally weather as far north as Lat. 5° or 6° N. In this area the squalls were more severe than on the 11th, and rain was falling more or less steadily and continuously. This advance of a

humid, squally current of air is further confirmed by the change in the weather which had taken place during the previous 24 hours in Ceylon. The skies clouded over in that island, winds strengthened, and heavy rain began to fall on the afternoon of the 11th. Colombo, for example, received 3·42 inches during the day.

13th May.—The humid current in the south of the Bay continued steadily to advance northwards, and at noon of the 13th had reached Lat. 9° or 10° N. The winds increased in strength, squalls were more frequent and severe, and the rainfall more continuous and intense. The *Udston*, in Lat. 7° N. and Long. 85° 47′ E., had hard squalls during the day. The *Kalima*, in Lat. 6° 20′ N. and Long. 84° 40′ E., at noon, experienced variable winds, violent squalls and constant rain during the day. The steam ship *Bhundara* was, as on the previous day, a little in advance of the area of squally weather, and hence was travelling northwards at nearly the same rate as the advancing south-west monsoon current. She was at noon in Lat. 11° 55′ N. and 83° 56′ E., and had light variable winds and calms and fine weather. Skies were overcast, but she received no rain. Further north the ship *Iolanthe*, which was advancing northwards to Calcutta in the neighbourhood of the Burma coast (near Cape Negrais), had light airs and calms, and made only 10 miles during the previous 24 hours. Hitherto the squally unsettled weather had been confined to that part of the Bay of Bengal in the immediate neighbourhood of the equator in which cyclonic storms never occur. But, with the northward extension of the strong, humid, south-west monsoon winds, the accompanying atmospheric disturbance reached a portion of the Bay where under favourable conditions squally weather may develop into a cyclonic storm.

History of the cyclonic storm.—*14th May.*—This change occurred, as will now be shown, during the next 24 hours. A largish fall of the barometer had taken place during the previous night at Port Blair and Nancowry. The winds had shifted during the previous 48 hours from south-south-east to south-south-west at Nancowry, and from north-west to south-east at Port Blair, and increased very considerably in strength and were nearly three times as powerful on the morning of the 14th as on the 13th. The wind directions had shifted (on the west coast of the Bay south of Vizagapatam) round from south-west to directions between north-east and north-west. Strong westerly winds were blowing steadily at the Ceylon ports. These winds show clearly that a cyclonic circulation was now established over the centre of the Bay, and the history of the cyclone hence dates properly from this day.

Heavy rain continued to fall in Ceylon, and moderately heavy rain set in at Port Blair and Nancowry, which were now receiving the first showers from the advance of south-west winds. The wind directions and barometric observations recorded on board ships, as well as at the coast stations, show that a barometric depression, the centre of which was at noon in about Lat. 11° N. and Long. 89½° E., had begun to form over which the air was moving cyclonically. The logs of the vessels in the Bay indicate that the weather in the south of the Bay was becoming more and more unsettled and threatening, the squalls more severe, and the winds cyclonic in intensity, as well as in direction.

The *Belfast*, in Lat. 1° 10′ N. and Long. 88° 31′ E. at noon had hard squalls and increasing winds. The *Kalima* in Lat. 8° 32′ N. and Long. 84° 33′ E., experienced constant rain and violent squalls. The *Udston* in Lat. 10° N. and Long. 86° 49′ E., had winds of force 9 from the north-west, with violent squalls at frequent intervals and a high sea. The *Bhundara*, which had advanced to Lat. 15° 46′ N. and Long. 84° 45′ E., had light variable breezes and fine weather during the day, so that she was, as hitherto, just beyond the area of disturbance and unsettled weather. The steam-ship *Brindisi* in the same latitude, and 100 miles further west, had clear skies and a calm sea. The *Iolanthe* in Lat. 16° 27′ N., and Long. 92° E., had hazy weather, light east-south-east winds, but a south-east swell (evidently due to the cyclone) began to roll up. At the head of the Bay the weather was fine but hazy, and the sea calm.

Hence we see that the disturbance which was now developing into a cyclonic storm had commenced as squally weather and heavy rain near the Equator, and that this state of the weather had extended northwards and increased in severity and violence, and when it had advanced beyond Lat. 8° or 9° it had changed in character. Hitherto there had been no centre of action. The weather had been squally, with heavy rain showers, but the winds had not shown regular and continued convergence to a centre of indraught. During the previous 24 hours, a definite centre, about which the actions were taking place, had been established. The barometer fell most rapidly at and near it, rain was heaviest in its neighbourhood, squalls were very violent, and the winds between the squalls not only increased in force, but showed that indraught to a centre which is the characteristic of a cyclonic circulation and storm.

15th May.—Hence we have now to follow the march of this cyclonic whirl which had developed out of the squally weather in the south of the Bay. Strong, steady, south-westerly winds were blowing at the Ceylon ports, but little or no rain fell in Ceylon during this day. In the east of the Bay very strong winds continued to prevail at Nancowry and Port Blair, and had extended during the previous 24 hours to Diamond Island, where rain had also commenced to fall. Winds also strengthened on the west coast of the Bay, and were already above their usual force in May. The observations extracted from the logs of the vessels show that the centre of the cyclonic storm was at noon in Lat. 13° N. and Long. 90° E., so that it had advanced about 150 miles during the previous 24 hours. The *Belfast* of Liverpool, in Lat. 3° 49′ N. and Long. 88° 33′ E. at noon, had south-west winds of force 8, and huge seas from west and west-south-west, but no rain. The *Kalima* and *Udston* were nearest to the centre and experienced very rough weather. The *Kalima*, in Lat. 11° N. and Long. 85° 50′ E. at noon, had frequent squalls, during which the winds blew with great force, and intervals of calm. The *Udston*, farther east in Lat. 11° 18′ N. and Long. 87° 30′ E., had terrific squalls with heavy forked lightning and a high cross sea. Squally weather and disturbed sea appear to have extended to about 4° north of the centre, or to Lat. 17° N., at noon, as the *Pemba* in Lat. 15° 33′ N. had a strong gale, and the *Iolanthe* in Lat. 17° 20′ N. had steady winds, a high sea and threatening weather. The *Bhundara*, which was in Lat. 19° 16′ N. and Long. 86° E. at noon, had light airs and hazy weather, and the *Brindisi*, in Lat. 19° N. and Long. 86° 17′ E., fine clear weather and a

calm sea. The *Comet, Meteor* and *Star* floating light-vessels off the mouth of the Hooghly all reported fine and hazy weather, smooth sea and light winds.

16th May.—The observations of the 16th show that the disturbance had now become a violent and dangerous cyclonic storm. The storm area had not as yet extended to the Bengal and Orissa coasts, as light southerly winds continued to blow during the day at Saugor Island and False Point, and the weather was fine, with passing clouds and sea slight. The winds at Akyab had backed from south-east to east, with the northward advance of the cyclone, but were as yet very light. Skies had clouded over on the Arakan coast, and light drizzling rain was falling.

The various observations, when charted, establish that the centre of the storm was at noon of the 16th in Lat. 15° 45′ N. and Long. 90° 45′ E., and was travelling northwards at a rate of nearly nine miles an hour. It was therefore at that time about 300 miles due west of Diamond Island and Cape Negrais. Very strong winds prevailed over the Bay to the south of the depression and storm area, and winds of hurricane force in the storm area itself; whilst further north they diminished rapidly in strength and at the head of the Bay were very light, and almost the same in direction on the morning of the 16th, as if the storm had not existed.

The ship *Belfast* of Liverpool, in Lat. 5° 45′ N. and Long. 87° 37′ E. at noon, experienced south-west winds of force 7 to 8 during the day, with fine weather and a very high sea. The *Udston* whose position at noon is stated in the log to have been in Lat. 11° 54′ N. and Long 87° 3′ E., or upwards of 300 miles to the south of the centre, experienced very stormy weather. The wind during the day blew from all points of the compass with terrific force (varying from 10 to 12). Heavy rain fell throughout the day, and the sea ran very high. The steam-ship *Pemba*, which left Rangoon for Calcutta on the afternoon of the 14th, rounded Cape Negrais, and passed into the Bay of Bengal on the evening of the 15th. She was in Lat. 17° 10′ N. and Long. 91° 17′ E. at noon, and had furious squalls during the afternoon, and weather became rapidly worse, so that after 8 P.M. it blew a hurricane, with high confused sea and blinding rain.

The weather to the north and north-west was in remarkable contrast to that in the centre and south of the Bay. The *Bhundara*, anchored off Pooree, had light airs. The *City of Khios*, in Lat. 16° 46′ N. and Long. 86° 10′ E. at noon, had light north winds of force 2 during the whole day. Skies were clouded, but the weather was fine throughout. The *Clan Mackintosh*, in Lat. 15° 11′ N. and Long. 82° 29′ E., was, like the *City of Khios*, advancing northwards at about the same rate as the storm. She experienced very hot and sultry weather, with overcast skies and light winds.

Hence, as hitherto, the cyclonic storm was a small feature in front of a large area of very strong humid southerly winds. The storm had marched northwards with the northward extension of the area of southerly winds and was apparently impelled or carried forward by these winds. It was influencing the weather and winds over the greater part of the north of the Bay, but it was as an intruding element, and its influence was not felt to any marked extent at

distances greater than 150 to 200 miles to the north and west of the storm centre.

17th May.—The character of the storm and the path of the centre on the evening of the 16th and morning of the 17th are known accurately from series of observations taken on board the *Rajputana* and *Pemba* steamers on the Burma lines of the British India Steam Navigation Company. The *Rajputana* was proceeding from Calcutta to Rangoon. She passed out of the Hooghly on the afternoon of the 15th. The weather was then fine, with light easterly winds. Her direct path lay across the front of the cyclone. As she advanced the weather changed and became very threatening. The winds increased rapidly in force and hauled round, and at last, when the vessel was not more than 150 miles from the storm centre, the barometer began to fall slowly.

The position and direction of line of march of the cyclone which the steamer was now evidently approaching were accurately judged, and the captain judiciously changed his course from south-east to south-west for some hours, and thus passed round the cyclone in its westerly and southerly quadrants. The *Rajputana* was nearest to the centre at 4 A.M. of the 17th, when it was in Lat. 17° 50′ N. and Long. 91° 20′ E., and about 95 miles to the east of the vessel. She experienced from 1 A.M. until 8 A.M of the 17th a very heavy gale, with terrific squalls. As she proceeded eastwards to the south of the Burma coast, the weather improved rapidly.

The *Pemba* left Rangoon on the afternoon of the 14th for Calingapatam, a port on the opposite coast of the Bay, between Vizagapatam and Gopalpore. She passed the Alguada Reef at about mid-day of the 15th, and then proceeded almost due west across the Bay. This brought her in front of the storm on the 16th. The weather became rapidly worse on the afternoon and evening of the 15th. A strong gale from north-east, force 10, with heavy rain, was blowing at 7 A.M. of the 16th. It blew a strong gale, with furious squalls, after noon, and the course of the vessel was then changed to north under easy steam. The barometer fell rapidly during the day, and before 8 P.M. it blew a hurricane with a high confused sea and blinding rain. The barometer was lowest at 2 A.M. of the 17th when the corrected reading was 29·09″. The *Pemba* was at that hour about 10 or 15 miles to the west of the centre. It is hence probable that the barometric height at the centre of the storm was not at that time lower than 28·9″. The weather began to moderate as the storm centre advanced northwards from the steamer, but strong winds and violent squalls were experienced until the evening of the 17th.

The various observations (especially those taken on board the *Rajputana*) indicate that the centre, which had hitherto moved in a northerly direction, began to curve to east on the afternoon and evening of the 16th. This motion to the east of north became more marked on the 17th. There were no ships in the immediate neighbourhood of the centre of the storm on the 17th. The various observations show that it was approximately in Lat. 19° N. and Long. 91¾° E. at noon of the 17th. It had therefore advanced about 240 miles during the previous 24 hours, *i.e.* at the rate of 10 miles per hour.

The character of the weather in the Bay is clearly indicated by the ship observations. The ship *Udston*, in Lat. 14° 24′ N. and Long. 86° 44′ E. at noon had south-west winds of force 9 and a high cross sea. The *Belfast* of Liverpool in Lat. 8° 38′ N. and Long. 85°46′ E. experienced fresh south-west winds of force 8, and the *Sea Nymph* in Lat. 7°13′ N. and Long. 85° E. had strong winds, overcast skies and a hazy atmosphere, but no rain. The *Iolanthe* at the head of the Bay in Lat 21° N. had calms and light winds, the *Clan Mackintosh* in Lat 18° 22′ N. and Long 86° E. light airs, hazy weather and overcast skies, and the floating light-vessel *Comet*, at the entrance to the Hooghly, north-east airs of force 1 and cloudy weather. Hence strong winds prevailed over the whole of the Bay to the south of the disturbance. They fed the storm, but they did not form an integral part of the cyclonic circulation, and the direction of the centre could not have been accurately ascertained from them. Winds were strong for some distance to the north and west of the centre, but at distances of 150 miles and upwards they were exceedingly light, and in the neighbourhood of the Bengal and Orissa coasts were much feebler than the ordinary winds of May. The chief indication on the Bengal coast of bad weather to the southward was the very heavy swell which came up from the south-east.

The centre advanced in a north-north-east direction to the Arakan coast on the afternoon of the 17th.

Winds increased slightly in force on the 16th at Akyab. The weather began to be squally, with rain, on the morning of the 17th, and the sea to rise. The barometer commenced falling at 10-30 A.M., and at mid-day the squalls became more frequent and violent. The wind increased to a gale at 4 P.M. and the weather was then very threatening, with frequent furious squalls. The squalls blew with terrific force, and heavy continuous rain fell after 7 P.M. and the sea continued to rise. The barometer fell to 28·98″ at 8-45 P.M., when the cyclone was at its worst and blowing with enormous force from the east-south-east. A short lull of five minutes occurred at 9 P.M., after which the wind suddenly shifted to south-south-west. The weather began to moderate very slowly afterwards, but the wind blew hard all night, with heavy and violent gusts.

May 18th.—The cyclone was now advancing directly to the Arakan Hills, which are of considerable elevation, averaging 3,500 feet and rising in their highest peaks to 7,000 feet. They proved to be too large an obstacle for the storm to surmount, and caused a rapid destruction of the cyclonic motion. Before 10 A.M. of the 18th the storm had completely broken up and disappeared. Light irregular winds and calms prevailed on the Arakan coast, and moderate south-west winds (decreasing in intensity as the day advanced) with cloudy and hazy weather over the Bay generally. The *Belfast* of Liverpool in Lat. 12° 6′N. and Long. 85° 13′ E. had fresh monsoon winds throughout the day. The log of the *Sea Nymph* (in Lat. 10° N. and Long. 84° E. at noon) records that the south-west winds in the part of the Bay she traversed decreased from force 7 to 4 during the course of the day. The *Kalima* in Lat. 18° 30′ N. and Long. 85° 19′ E. had light south-west winds and fine clear weather, and the *Japan* in Lat. 19° 41′ N. and Long. 89° 6′ E. had moderate south-south-west breezes (force 3) and fine clear weather.

An interval of about a fortnight elapsed, during which fine weather, with light to moderate winds and occasional squalls, prevailed in the south of the Bay, after which another advance of powerful moist south-west winds carried the rains up into Burma and Bengal.

The storm proper was, then, of comparatively small extent. It was remarkable as much for the strong south-west winds which blew at distances of 300 to 500 miles to the south, as for the very light winds that prevailed at distances of upwards of 100 or 150 miles to the north and west.

Storm wave.—The calm area passed over Akyab, but was apparently of small extent. A storm wave broke over the Arakan coast and inflicted much loss upon the crops and grain stored up. About 100 people are reported to have been drowned or killed by falling houses during the storm.

Summary of facts.—The storm formed on the 14th and 15th to the west of the Andamans, and in front of the first local advance of monsoon winds up the Bay. It moved northwards on the 15th and 16th, and on the 17th recurved through N.-N.-E. to N.-E., and finally crossed the Aracan coast at Akyab about 9 P.M. on the 17th, and broke up shortly afterwards without crossing the Aracan hills. The storm-area was oval-shaped, the longest diameter on the 16th and 17th approximately coinciding with the direction of motion of the storm.

There are no data for the determination of the magnitude of the storm centre in this storm, beyond the fact that there was a lull of five minutes at Akyab when the centre was passing over the station. As the storm was then moving at the rate of 15 miles at least, this would prove that the breadth of the central area was at least 1¼ miles.

The path of the storm is approximately given by the following data:—

Day.	Hour.	Position.		Distances passed over in previous 24 hours.	Rate of advance in miles per hour during previous 24 hours.
		Lat. N.	Long. E.		
14th . .	Noon	11° 0′	89° 30′	150	6
15th . .	Noon	13° 0′	90° 0′		
16th . .	Noon	15° 40′	90° 45′	190	8
17th . .	2 A.M	17° 30′	91° 10′	130	9
„ . .	Noon	18° 55′	91° 45′	105	10½
„ . .	9 P.M	20° 30′	93° 0′	135	15

The following table gives the lowest barometric reading on each day during the progress of the storm:—

Date and hour.	Observation.		Observation where recorded.
	Actual.	Probable corrected.	
16th, midnight . .	28·86	29·14	On board the *Pemba*, about 20 miles from calm centre.
17th, 2 A.M. . .	28·83	29·09	Ditto ditto.
„ 8-45 P.M. . .	29·10	28·98	Akyab observatory, when calm centre passing over it.

The following table gives the data showing distances at which winds of force 8 or upwards were observed:—

Date.	Ship.	Bearing and distance of centre at noon.	Force.	Wind direction.
May 14th	Udston	200 miles E. by N.	9	N.-W.
„ 15th	Udston	210 „ North-East	11	W.-N.-W. to S.-W.
„ „	Pemba	329 „ West-South-West	8	S.-E. by E.
„ 16th	Udston	352 „ North-East	10 to 12	W.-N.-W. to S.-W.
„ „	Pemba	105 „ South-South-West	12	E.-N.-E.

A series of wind observations of unusual accuracy were carefully taken on board the *Rajputana*, from which the following results, giving the bearing of the centre with respect to the wind direction at intervals of two hours, have been worked out:—

Ship.	Time.	Wind direction.	Distance and bearing of centre.	Bearing angle.
Rajputana	17th 2 A. M.	N.	110 miles E.-S.-E.	112°
	„ 4 „	N.-N.-W.	114 „ E.	112°
	„ 6 „	N.-W.	125 „ E. by N.	124°
	„ 8 „	W.-N.-W.	125 „ E.-N.-E.	135°.
	„ 10 „	W.-N.-W.	140 „ N.-E.	112°
	„ Noon	N.-W by W.	170 „ N.-N.-E.	86°
	„ 2 P. M.	W.	190 „ N.-N.-E.	112
	„ 4 „	W.-S.-W.	210 „ N.	112

The average of all the values of the bearing angle in the case of the *Rajputana* is 113°, or ten points almost exactly.

The mean of the values of the bearing angle as determined by the wind directions at Akyab from 4 P.M. to 8 P.M., is 116°.

HISTORY OF THE STORM OF 26TH JUNE TO 4TH JULY 1883.

This is an example of the class of storms which are generated during the rains (that is between June 15th to September 15th). The great majority of these storms form in the immediate neighbourhood of the land, and hence ships coming up the Bay mainly experience the weight of the westerly and southerly winds which feed into them. They give strong westerly gales near the head of the Bay to vessels bound for the Hooghly, and the storms are sometimes described as westerly gales. They are true cyclonic storms, and as such to be avoided, if possible, by the mariner.

Weather previous to the formation of the storm.—The south-west monsoon of 1883 set in over the Bengal coast districts in the first week of June, but was feeble. It gave moderate rain for a few days. A small storm began to form on the 12th between False Point and Saugor Island. It passed across the Balasore coast on the 14th and drifted through Chutia Nagpur

into Behar, to a portion of which it gave excessive rain. The following gives the total rainfall from the 15th to the 17th at several places over which it passed.

Gya	10·26 inches.
Behar	22·17 "
Patna	12·71 "
Mozufferpore	15·42 "
Hajipur	14·76 "

The disturbance broke up on the 18th and 19th, and was followed by a partial cessation of the rains in Bengal. The air became drier, skies were less clouded, and the winds fell off in strength. In the Bay south-west monsoon winds prevailed everywhere, but they were nowhere of force greater than 3 or 4, except during occasional rain squalls, such as occur at intervals during the prevalence of the south-west monsoon in the Bay.

The observations of the 25th June showed that a marked change in the weather was commencing. The barometer in South Bengal was two-tenths of an inch above its normal height. Winds were very unsteady and variable in Bengal and over the north of the Bay. Heavy rain squalls and dark overcast skies prevailed over the south-east of the Bay between Lat. 14° and 19° N., and close sultry weather with calms or light airs, clear skies and a smooth sea to the north of Lat. 20° N.

Over the greater part of the Bay south-west winds were blowing, but they were unusually light, and weather was fine in the north and centre. Thus, the *Bancoora*, passing round Ceylon and entering the Bay, had light to moderate breezes and fine weather. The steam-ships *India*, *Himalaya*, and *Roma*, all in the centre of the Bay in about Lat. 16° N. had moderate breezes and cloudy skies with occasional rain squalls. The *Comilla*, in Lat. 20° 13′ N. and Long. 92° 28′ E., had fine clear weather and a smooth sea, and the *Prince Amadeo*, in Lat. 19° 23 N. and Long 85° 56′ E. gentle winds, close sultry weather and a smooth sea. These brief extracts sufficiently establish the character of the weather in the Bay on the 25th. There was no indication of stormy weather at this time in any part of the Bay. Moderately strong south-west winds, of force 3 to 5 or 6, were blowing over the south-east of the Bay, near the Andamans and Nicobars. They were evidently not continued northwards, as the winds at the head of the Bay were very light and variable. That these winds were converted into an ascending column of air was shown by the fact that the barometer now began to fall rapidly over the north of the Bay, and to a much less extent over India. The winds in the south and centre of the Bay increased in force during the day, and weather became squally and unsettled near the head of the Bay on the 26th. Thus, the *India*, in Lat. 19° 36′ N. and Long. 86° 33′ E., had strong winds and squally weather on the morning of the 26th. The *Amadeo*, about 40 miles to the north-east of that vessel at noon, had heavy cloudy unsettled looking weather, with much lightning during the day. The *Comilla*, in Lat. 22° 21′ N. and Long. 91° 50′ E., had squally weather, with very heavy continuous rain during the afternoon and evening. These were the first indications of the impending storm. The weather became more unsettled and threatening in appearance during the day; heavy rain began to fall in the north of the Bay; the barometer fell rapidly, and winds began to draw into the area of falling barometer from the north, as well as the south.

Heavy rain also commenced in the neighbourhood of the Aracan Coast and increased the force of the south-west winds in the north of the Bay, and the disturbance thus occasioned was shortly afterwards followed by the formation of a whirl near the head of Bay. The winds on the Bengal Coast, although still feeble, settled down to north-east, the usual indication during the rains of the formation of a cyclonic whirl at the head of the Bay.

History of the Storm.—*June 27th.*—This whirl gained rapidly in force during the night of the 26th, and on the morning of the 27th it had developed into a small but dangerous storm. The chief features of the storm at this time were the violent winds in the south-east and east quadrants. The centre of the cyclonic circulation at noon of the 27th was in Lat. 20½° N. and Long. 89¾° E. or about 100 miles to the south-south-east of Saugor Island. The British Indian steam-ship *Pemba,* which was in Lat. 16° 13′ N. and Long. 93° 30′ E. at noon, and was advancing northwards along the Burma Coast, had "a strong gale, with furious squalls, which blew away the sails and awnings in the afternoon;" and the *Comilla,* in Lat. 22° 21′ N. and Long. 91° 50′ E. at noon, had "hard squalls and wild squally weather" between 4 P.M. and midnight. In the western and northern quadrants skies were overcast with rain, and weather was unsettled with occasional squalls, but the winds were as yet feeble, varying in force from 1 to 4 or 5, except perhaps in the immediate neighbourhood of the centre.

A large number of vessels were off the mouth of the Hooghly, waiting to enter the river. Their logs agree in stating that the winds were unsteady and variable in direction, but increased considerably in force during the day, the weather became more unsettled and squally, skies were overcast, and heavy rain showers fell at frequent intervals. The centre of the disturbance was almost stationary on the 27th. If it was moving, its rate of motion was so small as not to produce any appreciable change of wind direction, as recorded on board the light vessels and pilot vessels near the entrance to the River Hooghly.

June 28th.—The storm continued to increase in intensity during the night of the 27th, and on the morning of the 28th the barometer had probably fallen to 29·00″ at the centre, as readings between 29·1 "and 29·2" were recorded on board ships at distances of 20 to 40 miles from the centre during the day. The various observations taken on board ships indicate that the centre at 10 A.M. of the 28th was in Lat. 21° N. and Long. 88° 45′ E., and moving west by north at a rate of about 3 miles per hour.

The weather over the north of the Bay was now very wild and stormy. The following gives the weather reports in full of several vessels near the head of the Bay which encountered the weight of the storm in different quadrants.

The *Comilla* at noon was in Lat. 21°4′ N. and Long. 89° 31′ E. and proceeding from Chittagong to Calcutta, and hence in the eastern quadrant at some distance from the centre. At 4 A.M. she had a very high sea from south and south-west. Winds were very variable in force, with very hard squalls from south-south-west. At noon hard squalls came up from the south-south-west. At 6-30 P.M. there was very heavy rain, and a tremendous sea from south-south-west and south-west. At 7-30 P.M. a terrific sea carried away the starboard cutter. At 8 P.M. terrific squalls from south-west passed over the vessel, which split the

new jib and staysail. At midnight the winds were from south-west and of force 11.

The *Saint Magnus* and *British Princess* were in the south-west quadrant during the greater part of the day, and about 40 miles from the centre, when they were nearest. The weather as described in the log of the *British Princess* was as follows :—

4 A.M.—Heavy rain, lightning and thunder, high confused sea.

8 A.M.—Heavy squalls, with torrents of rain.

Noon.—Fresh gale : high and confused sea.

8 P.M.—Heavy squalls, torrents of rain, high sea.

Midnight.—Force of wind 11. Furious squalls, torrents of rain and high sea.

The log of the *Saint Magnus* runs as follows :—

4 A.M.—North-west wind, force 6. Heavy gusts and heavy continued rain.

8 A.M.—Wind north-west, force 6. Strong winds and high sea.

Noon.—Wind north-west, force 4. Winds and sea more moderate.

4 P.M.—Wind west-south-west, force 6. Terrific squalls. Tremendous seas at times.

Midnight.—Wind south-west, force 10. Furious gale, high squalls and heavy sea.

The *Pemba*, about 200 miles to the south-east of the centre, had strong gales (force 9) with a heavy sea. The light-vessels at the entrance to the Hooghly, which were only about 30 miles to the north or north-west of the centre, had winds not exceeding 5 in force during the day, and it was not until late in the evening that they began to experience the strong winds of the east quadrant and felt the force of the storm. The contrast between the violent winds and furious squalls in the southern and eastern quadrants at considerable distances from the centre (up to 150 or 200 miles), and the moderate winds and squalls at distances of 30 or 40 miles in the northern and western quadrants is one of the most conspicuous features of this storm, and probably of all the small cyclonic storms of the rains proper.

June 29th.—The observations of the 29th show that the barometer had fallen rapidly in South-West Bengal and Orissa, and was nearly half an inch below its normal height in June. Winds were from two to four times their ordinary strength in June, and very heavy continuous rain had fallen during the preceding 24 hours over the whole of Orissa and South-West Bengal. These observations and the logs of vessels show that the storm continued to increase in extent during the night of the 28th, and covered a larger area than it had hitherto done. It intensified slightly, but there is no evidence that the barometer fell below 29·0" at any time during the storm. The lowest recorded readings were 29·14" at the Upper Gasper light-ship at 10 A.M., and 29 108" at 4 P.M. of the 29th. The storm centre continued to drift slowly to the westward during the night of the 28th, and was in Lat. 21°30′N. and Long. 87°55′. E. at 10 A.M of the 29th, or about 35 miles to the west by north of its position at 4 P.M. on the previous day, and was advancing at a rate not exceeding 3 miles per hour. It had passed between the Intermediate and Upper Gaspar light-vessels, and

was now about 5 miles to the west. The vessels inthe north of the Bay continued to experience violent cyclonic winds and a dangerous sea. The *Pemba*, 200 miles to the east in the morning, had a fierce gale, with high irregular sea and hard squalls blowing with hurricane force. The log of the *Comilla*, which was about 60 miles to the east of the centre, describes the weather in the eastern quadrant as a "terrific storm, continued rain, squalls of hurricane force, with a mountainous and dangerous sea running." The *Saint Magnus* was about 45 miles to the east of the storm, and experienced a heavy gale with terrific gusts and a high sea; the *Prince Amadeo*, 75 miles to the east, a strong gale with furious squalls and a very high sea. All the ships' logs agree in assigning a force of 10 and 11 to the winds in the southern and eastern quadrants. At Saugor Light-house, which was only 20 miles to the north of the centre at 10 A.M., moderate winds were felt, and at the Upper Gasper light-vessel, not more than 5 to 10 miles to the north of the centre, the winds were of force 5 to 6.

The captain of the *Comet* floating light-vessel thus describes the weather on the 29th—" Weather was very threatening in the morning, and a heavy sea came up from the south-east. The wind was very variable, shifting all round the compass. Rain-squalls passed up frequently. At midnight it was blowing a furious gale." The captain of the *Meteor* floating light-vessel describes it as follows. "The sea was very rough, and a squall from south-west came up at 8 A.M. of the 29th. Frequent heavy rain-squalls passed over the vessel. The wind shifted to south-west at 10·30 A.M. The barometer began to rise at 2 P.M. During the evening a strorg south-west gale blew, and frequent terrific rain-squalls passed over the vessel."

The centre was in Lat. 21°35′ N. and Long. 87′30′ E. at 4 P.M. of the 29th, and its velocity was now increasing. Its rate did not however yet exceed 5 miles per hour.

June 30th.—The storm centre crossed the Orissa Coast between False Point and Balasore during the night of the 29th, and was advancing through Orissa on the morning of the 30th. Its position at 10 A.M. of the 30th was in about Lat. 22° 0′ N. and Long. 84° 0′ E. It was hence travelling much more rapidly than hitherto. The depression at the centre was not so great, and the air-motion was not so regular as at sea. This was evidently due to the resistance and action of the Orissa hills. The weather rapidly improved at the head of the Bay. The *Pemba* had a moderate breeze and clear weather at noon of the 30th; the *Saint Magnus* a strong breeze with hazy weather at noon, and moderate and fine weather at 8 P.M., and the *Comilla* had overcast hazy weather at noon, and fine weather at 4 P.M. All these vessels were to the north of Lat. 20° N.

The above account illustrates fully the chief features of the more dangerous storms of the rains proper in the Bay of Bengal. They commence to form after a partial cessation of the rains in Bengal. Heavy rain begins to fall generally near the Arakan Coast or at the head of the Bay. This causes a greater inrush of moist winds from the south, which not only prolongs and intensifies the rainfall, but generally sets up a whirl near the head of the Bay, which, if conditions are favourable to its growth, increases and intensifies and becomes in the course of a day or two a dangerous storm. The most prominent feature of these storms

is the very violent winds and furious squalls in the south-east quadrant, which extend to very considerable distances from the centre. The storm moves very slowly in the earlier stages, and hence the stormy weather or westerly gales attending them may continue for several days; but when the cyclone is fully developed it generally moves or shoots off rapidly to the Orissa Coast (or the Bengal Coast, but much more rarely), and very shortly after it passes landwards the weather begins to improve at the head of the Bay, and the winds decrease in force, and in a short time normal or ordinary south-west monsoon winds (force 3 to 5) are again established at the head of the Bay.

July 1st.—The history of the storm after it reached the Orissa Coast is given more briefly. The centre travelled at a mean rate of about 15 miles per hour on the 30th, and was in about Lat. 22° N. and Long. 81° E. at 10 A.M. of the 1st. The storm gave excessive rain to Orissa, and very heavy rain fell in the districts of the Central Provinces through which it passed on the 1st, which flooded the rivers and carried away bridges on the railways and roads and interrupted traffic.

July 2nd.—It passed out of the Central Provinces into Central India on the morning of the 2nd. The centre was near Indore at 10 A.M. in Lat. 22½° N. and Long. 76° E., so that it had advanced at a mean rate of about 14 miles per hour during the previous 24 hours.

July 3rd.—It crossed through Guzerat into Cutch, and was between Bhuj and Rajkote in Lat. 23½° N. and Long. 69¾° E. at 10 A.M. of the 3rd. It had continued to give excessively heavy rain to the districts through which it marched. At Rajkote 9·85 inches were recorded on the 3rd. The storm had thus advanced unbroken across the head of the Peninsula from the Orissa Coast to Cutch, a distance of 1,400 miles, in about 80 hours. It was now in the immediate neighbourhood of the Arabian Sea, into which it passed during the afternoon of the 3rd.

July 4th.—It continued to exist as a dangerous storm for at least 36 hours longer as it passed over the British Indian Steamer *Oriental* on the evening of the 4th in Lat. 24° 14′ N. and Long. 63° 30′ E., or at a distance of about 400 miles from the Cutch Coast. The following is the account of the storm given by the captain of the *Oriental*:—"I experienced a very heavy cyclone on the night of the 4th July in Lat. 24° 14′ N. and Long. 63° 30′ E. at 8 P.M. I had a light westerly breeze, with the usual south-west swell on the morning and afternoon of the 4th and the barometer was steady until 9 P.M., at which hour the wind began to increase slightly, hauling northerly. As I noticed the glass was falling rapidly, I gave the order to take in all sail. While clewing up the fore-topsail, the whole force of the cyclone struck her, carrying away fore-topsail, foresail, and awnings fore and aft. I at once eased down to keep her before the wind till the saloon sky-lights could be secured, as I was afraid to bring her to the wind till they had been secured. At 11-30 P.M. a sea carried away both quarter boats on the starboard side. At midnight I brought the ship to the wind and sea. The reading of the barometer at that time was 28·56″. Violent winds continued until 4 A.M., when the wind commenced to moderate. The sea continued very heavy, and I was not able to stand on my course until noon."

It would appear from this account that the storm not only intensified again after leaving the coast, but that it moved more slowly than while crossing the land. In both respects it agrees with what has been observed in other storms that have passed into the Arabian Sea from the Bay of Bengal.

It will thus be seen that this class of storms is remarkable chiefly for the contrast between the strong winds which are experienced at very considerable distances to the east and south of the centre, and the light winds at distances not exceeding 30 miles to the north and west of the centre.

Summary of the Storm.—This storm began to form on the 25th at the head of the Bay after a short break in the rains which followed the first large advance of monsoon winds up the Bay into Bengal. It remained almost stationary on the 26th and 27th, and began to move very slowly to the westwards on the 28th and crossed the Balasore Coast a few miles to the north of Balasore about midnight of the 29th. It marched in a westerly direction across the Orissa Hills into the Central Provinces, diminishing to some extent in intensity and moving somewhat irregularly. It, however, began to draw large supplies of vapour from the Bombay Coast, and again increased in strength, and continued its march across the head of the Peninsula at an average rate of about 15 miles per hour. It advanced through Cutch, and thence passed out into the Arabian Sea on the evening of the 3rd, and was some distance to the south of Kurrachee on the morning of the 4th. It passed over the steam-ship *Oriental* on the evening of the 4th in Lat. 24° 4′ N. and Long. 63° 30′ E. or 220 miles west by south of Kurrachee. Nothing is known of its history after that date, but it probably broke up shortly afterwards. The storm had hence an unbroken existence of at least ten days. It presented comparatively small differences of intensity at different periods, taking into consideration the very different conditions of its existence at sea, and afterwards whilst advancing across the hills, plateaux and river valleys of the head of the Peninsula.

The following table gives the position of the centre at the hours stated, from the 27th of June to the date of its disappearance in the Arabian Sea beyond the limits of India, and its rate of motion throughout:—

Date.	Hour.	Position of Centre. Latitude N.	Position of Centre. Longitude E.	Distance travelled during preceding interval.	Rate of motion.
June 27th	Noon	20° 30′	89° 45′	...	...
	4 P. M.	20° 35′	89° 35′	12	3
,, 28th	10 A. M.	21° 0′	88° 45′	62	3½
	Noon	21° 3′	88° 40′	6½	3¼
	4 P. M.	21° 10′	88° 30′	13	3¼
,, 29th	10 A. M.	21° 30′	87° 55′	45	2½
	Noon	21° 30′	87° 50′	5½	2¾
	4 P. M.	21° 35′	87° 30′	22	5½
,, 30th	10 A. M.	22° 0′	84° 0′	230	13
	4 P. M.	22° 0′	83° 30′	32	5⅓
July 1st	10 A. M.	22° 0′	81° 0′	162	9
	4 P. M.	22° 0′	79° 45′	80	13⅓
,, 2nd	10 A. M.	22° 30′	76° 0′	245	13⅔
	4 P. M.	23° 30′	74° 30′	120	20
,, 3rd	10 A. M.	23° 30′	69° 45′	308	17
	4 P. M.	23° 45′	68° 45′	66	11
,, 4th	8 P. M.	24° 14′	63° 30′	300	12

The following table gives the lowest reading of the barometer at 10 A.M. the average barometric height at the place, and the amount of the greatest known barometric depression at 10 A.M. on each day:—

Date.	Place.	Lowest 10 A. M. barometric reading.	Average 10 A. M. barometric height, July 1st.	Barometric depression.
June 29th . . .	Bay (Sandheads) . .	29·140	29·602	·462
„ 30th . . .	Sambalpore . . .	29·353	29·589	·236
July 1st . . .	Seoni	29·463	29·624	·161
„ 2nd . . .	Indore	29·410	29·662	·252
„ 3rd . . .	Bhuj	29·326	29·616	·290
„ 4th . . .	Kurrachee . . .	29·380	29·589	·209

One of the most remarkable features of the storm was the strength of the westerly and southerly winds in the south and south-east quadrants, more especially when contrasted with the weakness of the northerly winds at distances of only 20 and 30 miles from the centre. The strong westerly and southerly winds extended south as far as Lat. 18° N., or to at least 300 miles from the centre.

CHAPTER IV.

BRIEF SUMMARY GIVING PRACTICAL HINTS TO SAILORS RESPECTING CYCLONIC STORMS IN THE BAY OF BENGAL.

In consequence of certain actions the air is frequently set into motion over a part or the whole of the Bay of Bengal in the manner which is usually described as cyclonic circulation. In an area over which a cyclonic circulation is for the time established the barometer falls from the outskirts to a point which is roughly speaking in the middle of the area. This part is called the centre of the cyclonic circulation. The air in a cyclonic circulation moves in a somewhat complex manner. It not only moves round the centre, but is also drawn in towards the centre, and when it approaches the centre is also carried upwards. The path of the air (and hence the direction of the winds) is not in circles, but is a species of spiral in which it approaches the centre as it moves round. The air moves round the centre in an invariable manner in each Hemisphere. In the Northern Hemisphere it moves in the following manner—south, east, north, west, or against the sun. The revolving motion is also sometimes described as counter-clock-wise, or as the same kind of turning or twisting motion which an ordinary screw makes when being withdrawn.

The weather in a cyclonic circulation in the Bay is usually cloudy and rainy, and sometimes stormy. There is a strong tendency at certain seasons of the year for any cyclonic circulation which has been established in the Bay to increase in extent and intensity, in which case it may give stormy weather and hurricane winds in the inner portion of the cyclonic circulation.

When the winds in any part of a cyclonic circulation are of force 8 to 10, and do not exceed force 10 in any part, that part of the cyclonic circulation is called a cyclonic storm. If the winds in any portion of it are of hurricane force (11 or 12), it is called a cyclone.

The use of the terms cyclonic storm and cyclone in this manner has been suggested by Mr. Blanford and is adopted in this book as most appropriate. A cyclonic storm or cyclone is hence that part of a cyclonic circulation in which winds are of force 8 and upwards, and is always of very much smaller extent than the cyclonic circulation of which it forms the inner part. Cyclonic circulations, and therefore also cyclonic storms, vary greatly in intensity and size. The intensity of a cyclonic storm or cyclone is usually measured by the amount through which the barometer falls in passing from the outskirts of the cyclonic circulation to the storm centre, and sometimes by the force of the strongest winds. The first is on the whole the best measure.

Cyclonic circulations are sometimes of vast extent, covering a whole continent or extensive oceanic area. In the Bay of Bengal cyclonic storms or cyclones are rarely more than 500 or 600 miles in diameter, and are frequently less than 100 or 150 miles in diameter.

The largest cyclones usually form slowly in the centre of the Bay (or to the west or north-west of the Andamans), and advance by the longest path before reaching land, *i. e.* to the north or towards the Bengal coast.

Cyclones usually increase in intensity as they advance from their birthplace to the coast, and are usually most powerful and dangerous just before reaching land.

Hence large storms in the Bay of Bengal are of two kinds—

1st.—Those in which there is a calm centre, an inner storm area of hurricane winds, and an outer storm area of violent winds. These are termed in the present book 'cyclones'.

2nd.—Those in which there is no well-defined calm central area, and in which the winds do not exceed force 10 or 11, and the barometric fall at the centre is not large, the barometer rarely falling below 29·00. These storms are termed in the present book 'cyclonic storms'.

By this notation the term 'cyclone' is restricted to the fiercest and most dangerous storms of Tropical seas, as was probably intended by Piddington, who introduced the word.

The Bay of Bengal is almost absolutely free from cyclonic storms or cyclones in the months of January, February and March. They are of rare occurrence in the month of April.

Cyclonic storms may occur at any time from the beginning of April to the end of December, but are most frequent during the months of July, August and September.

Cyclones are of occasional occurrence during two periods, known as the transition periods, which precede and follow the general prevalence of the south-west monsoon over India.

The first period extends from the beginning of May to the middle of June, and the second from the middle of September to the middle or end of December.

The largest and fiercest cyclones are met with in the months of October and November.

Indications of the Formation or Approach of a Cyclonic Storm in the Bay during the South-West Monsoon period from 15th of June to the 15th of September.

The first indications, or the chief features, of the weather in the north of the Bay antecedent to these storms are—

(1) Before a storm of this class commences to form the barometer is usually more or less above the normal height of the period, sometimes as much as two-tenths of an inch in the north of the Bay.

(2) Winds are very light and variable at the head of the Bay and frequently shift round to north and north-east at Saugor Island and False Point. At sea the chief feature of the winds is their lightness and variability, thus contrasting greatly with the normal winds of the South-West Monsoon.

(3) Weather is usually fine with passing clouds, but more or less unpleasant and oppressive in consequence of the great dampness

and stillness of the atmosphere. The atmosphere is frequently very clear. The rains are practically suspended in Bengal for the time being, and usually little rain beyond light local showers falls at the head of the Bay.

(4) Light to moderate south-west winds prevail in the south and centre of the Bay, with perhaps occasional rain-squalls. There is a strong tendency for the winds and squalls to increase in force.

Under such conditions cyclonic storms frequently form near the head of the Bay. The majority of the storms are feeble and of no great importance to sailors. The indications of the existence of a severe storm of this class are as follows:—

(1) A strong and squally monsoon over the south and centre of the Bay.

(2) Rapid increase in the strength of the south-west and south winds in approaching the head of the Bay. The winds in the southerly and south-easterly quadrants of the storm area are sometimes almost of hurricane force.

(3) A rapid succession of severe rain-squalls increasing in intensity and frequency as the storm area in the north of the Bay is approached and entered.

(4) Comparatively light cyclonic winds in the north-west and south-west quadrants, even at moderate distances from the centre. These give no indication of the strength of the winds in the opposite quadrants.

(5) As these storms occur in the midst of the South-West Monsoon and usually form close to shore near the head of the Bay, the indications given by sky, swell, &c., as to the position of the centre, &c., are usually very feeble, and of little use.

The rules for obtaining the bearing of the centre and track of a cyclonic storm of this class are the same asfor the cyclones of the transition periods. As they almost invariably formnear the head of the Bay and move westward across the Orissa coast or northward into Central Bengal, past experience is especially useful in indicating their probable path in any month.

INDICATIONS OF THE FORMATION OR APPROACH OF A CYCLONE IN THE BAY DURING THE MONTHS OF MAY, FIRST HALF OF JUNE, LAST HALF OF SEPTEMBER, OCTOBER, NOVEMBER AND DECEMBER.

The following are the chief features of the weather which immediately precede the formation of a cyclone in the Bay in the months of May, October, November and December:—

(1) Pressure is very uniform over the north and centre of the Bay and the Peninsula and the greater part of Northern India. The barometer is hence very steady and generally much higher than usual.

(2) Winds are very light and variable in the centre of the Bay. Light steady north-east winds prevail in Bengal and at the head of the Bay.

(3) Fine clear weather with smooth sea, and a very transparent atmosphere.

(4) South-west winds prevail over the south of the Bay, which increase in strength and give rain-squalls.

If the south-west winds increase in strength and pour large supplies of aqueous vapour into the area of light, variable winds in the centre or north of the Bay, they may give rise to a disturbance or cyclonic circulation, which may, under favourable circumstances, develop rapidly into a cyclonic storm or cyclone.

When a cyclone has formed, and begins to move northwards or westwards, the following changes occur, which are hence important indications of the existence of a cyclone in the Bay :—

(1) The barometer begins to fall in the Bay, at first very slowly, and afterwards more quickly.

(2) The south-west winds in the south of the Bay increase in strength, the weather becomes more squally and unsettled in the south of the Bay, cloud increases in amount and shows by its increasing movement indraught to a central or cyclonic disturbance.

(3) In the area to the north or west of the storm area which has formed the sky becomes less clear and transparent, and a veil of light cirrus appears and extends northwards. This veil thickens very gradually, and frequently gives rise to conspicuous halos round the sun or moon. These clouds at such a time frequently show very dark or vivid bright red colours at sunrise or sunset.

(4) Strato-cirrus or cirro-stratus clouds shortly after begin to appear below the cirrus clouds, and increase and extend outwards (*i.e.* northwards and westwards). The humidity of the air increases, the weather becomes more sultry and oppressive, and the wind begins to shift, and becomes steadier, and increases very slowly in force, in the north of the Bay.

(5) Shortly afterwards the first indications of the cloud bank are seen low down in the horizon. Its position is sometimes first shown at night by frequent, and in some cases almost continuous, lightning, which is seen by reflection from distant clouds. It is at this time so far off that no thunder is heard. This lightning and the cloud bank may be seen sometimes as much as 48 to 72 hours before the approach of the storm.

(6) The winds shortly after begin to freshen, cumulus and nimbus clouds appear in the horizon and gradually extend and cover the sky, and light drizzling rain begins to fall. Passing squalls then begin to come up, and the wind becomes more and more gusty. The squalls increase in intensity and frequency as the storm approaches.

(7) The storm gives rise to great agitation of the water surface which passes out from it as swell travelling rapidly outwards in all directions. In the north and west, where the winds are light, it is not mixed with swell due to the wind, and hence frequently one of the earliest indi-

cations at the head of the Bay of the existence of a cyclonic storm to the south is the setting in of increasing heavy swell.

It should be carefully noted that (3), (4), (5) and (6) are the indications in front of an advancing cyclone, and hence are observed in the north and west of the Bay, and more especially at the head of the Bay. In the south of the Bay (or in the rear of the storm) the indications are different and are given in (1) and (2). They are the prevalent strong squally south-west winds, the passage of frequent rain-squalls, increasing in frequency and force northwards, with constant thick cloud, gloomy weather, a heavy southerly or south-westerly swell. Occasionally the lower and middle clouds (more especially on moonlight nights) may be observed scudding with great rapidity northwards. As soon as the continued fall of the barometer, the increasing frequency and strength of the squalls, &c., indicate to the mariner in the Bay of Bengal that he is approaching a cyclonic storm, he should proceed to determine the bearing and course of the centre.

Bearing of the storm centre.—This is on the whole most easily determined to the north and west of the centre, or in the advancing semicircle. The following are occasional useful indications :—

(1) When the sky commences to cloud over with cirrus, the veil of this cloud usually appears most dense in a particular part of the horizon. It also shows occasionally very dark red tints at sunset and sunrise. This cirrus forms a kind of misty mantle which overlies the storm or hurricane cloud mass, and its direction is sometimes the first indication of the existence and general bearing of the cyclonic storm.

(2) When cirro-stratus clouds begin to show below the cirrus they frequently appear to diverge or radiate from a particular part of the horizon. In this case the focus or point of radiation or divergence corresponds nearly with the bearing of the centre.

(3) The direction of the centre of the cloud bank or of the lightning, which occurs almost continuously as soon as it begins to be visible, gives a very approximate estimate of the bearing of the cyclone. The cloud bank of a cyclone is easily distinguishable from all other cloud masses by its fixity of position and form. It retains its shape and position unchanged for hours, and it is only when the storm is in the immediate neighbourhood that it loses its remarkable appearance. As it approaches masses of clouds are seen to be torn from it.

(4) The direction of the swell which is produced by, and passes out from, the distant storm gives, in many cases, a fair indication of the direction of the distant storm. To the south of the storm the swell passing out from the storm and the swell due to the strong southerly winds feeding the storm give rise to a heavy cross swell. This is probably an almost unfailing indication of a cyclonic storm to the north.

Of these indications it should be noted that they are rarely observable to the south or east of the storm for obvious reasons. For example, the third indication (*viz.* that of the cloud bank) is useless to the south of the storm

centre, as the skies are more or less heavily clouded, and it is very rarely the dense fixed cloud mass of cyclonic storm can be perceived in the distant horizon.

The movement of the squalls in the case of the West India hurricanes (and probably in the larger cyclones of the Bay) is said to be at first from the cloud bank and diverging from it. The cumulus clouds of these squalls rise towards the zenith, spreading and covering the sky. The base of the cloud soon forms above the horizon the dark band characteristic of an approaching squall. With this cloud comes the rain when the wind freshens and veers to the right. Later, the squalls arise from the extreme portion of the cloud bank and follow the general movement of rotation of the meteor. If the scud above the cloud bank be noticed, it will be seen that it flies nearly parallel to it, so that an observer looking to the cloud bank sees it crossing from left to right. The lower clouds in the interior of the hurricane generally fly in directions to the right of the wind and nearly perpendicular to the bearing of the centre. It may also be noted that a squall frequently ushers in a shift of wind, and that the wind during a squall is almost invariably to the right of that prevailing previous to the squall.

The previous indications are useful in giving a rough approximation of the bearing of the centre or in confirming the conclusion derived from the use of the following rule :—

> *The bearing of the storm centre from any point within the storm area* (i. e. *area in which the winds are cyclonic in direction or are due to the cyclonic storm only*) *is at once obtained by observing accurately the direction of the wind and employing the table in page 129.*

which is based on the rule that "*to determine the bearing of the centre at any position within a cyclonic storm in the Bay of Bengal, face the wind exactly, and the centre is usually between 10 and 11 points to the right hand* (*and on the average almost exactly 10½ points*)."

The sailor should remember this is the best approximation possible based on previous experience, and that it may be out really or apparently to the extent of a point in each direction, more especially in the north-west angle of the Bay, when a storm is approaching.

Dangerous and manageable semicircle and advancing and retreating semicircles.—The storm area is divided into two parts in two ways. Sailors frequently consider it as divided into two parts or semicircles by the track of the centre. That to the right of the track is termed the dangerous semicircle, because the cyclonic winds and currents tend to carry the ship round and place her in front of the advancing centre, or in the most disadvantageous and dangerous position with respect to the storm. In the open sea it is the semicircle in which the maximum effort is required in order to avoid these dangers. The semicircle to the left of the track is called the manageable circle, because the winds of the storm can be utilized to run away from the inner storm area and centre. *This is usually done by running with the wind on the starboard quarter.*

A better division of the storm area (which is oval, and not circular in shape) in the case of cyclones in the Bay of Bengal, is by a line through he centre a right angles to the track, which usually divides the storm area into two halves of slightly different size. In the front half the barometer is falling and in the rear half it is rising. The line chosen divides these two portions, and hence marks at each instant all the places at which the barometer has fallen in consequence of the approach of the storm from that in which it is rising or beginning to rise. It is hence called the trough of the storm. The half in front may be called the advancing semicircle and the half in rear the retreating semicircle. When the character of the storms in the Bay of Bengal and of the coast, &c., are taken into account, it will be seen that the right-hand half of the advancing semicircle is by far the most dangerous portion of a cyclonic storm. This, which may be named the right advancing quadrant, is that portion of a cyclone which vessels leaving the Hooghly pass into in the case of the great majority of storms in the Bay, *i.e.* those which advance to the Orissa and Circars Coast.

It may also be noted that the least dangerous quadrant in the storms which advance to any portion of the north or west coast is the left advancing quadrant.

Position of the observer relative to the storm track.—If the bearing of the centre remains the same for some time (due to the centre advancing directly to the observer) this will be shown by the barometer falling and the wind increasing in strength, whilst its general direction remains unchanged (although it may shift for a short time in squalls). If the observer be in the storm area to the right or left of the track the wind will shift as the storm advances towards and past him. If the direction be not in the dangerous semicircle (as defined above) the wind veers or shifts with the sun through north, east, south, west, and if it shifts in this direction the observer is to the right of the track. In the manageable semicircle the wind backs or shifts against the sun, or through north, west, south, east, and if the wind shifts in this manner the observer is to the left or in the manageable semicircle.

Direction of the track or course of the cyclone centre.—It is always desirable that the probable track, as well as the bearing of the centre of a cyclone, should be determined as early as possible in order to keep as far away from the inner storm area of a cyclone and to bear away from it if the vessel be approaching it. The transition from the outer to the inner storm area is always comparatively sudden, and if the sailor delay in taking stock of the storm he may find himself involved in the inner storm area before he is prepared and when it is too late to do anything. Hence, shortly after the sailor is certain a cyclonic storm is approaching him and the wind direction has informed him in which semicircle and quadrant of the storm he is, he should lie-to for some time and see whether there is any permanent shift of wind. If he be in the south or south-east portions of the cyclonic storm in which strong squally winds extend to very considerable distances from the storm, it is probable he will observe no permanent change of wind even if he lies-to for some hours, and in that case he may conclude he is at a considerable distance to the south. He should, if advancing up the Bay either proceed slowly northwards or only take advantage of the southerly winds in the easterly quadrant by keeping well to the east of the storm centre, and should only adopt that course, if he is quite certain

the storm is either not a large one or if it is a cyclone that it is advancing westwards and there is no chance of its recurving eastwards near the head of the Bay.

If he be in any of the other quadrants of the storm area, and more especially if in the right advancing quadrant, he should lie-to until he observes a shift of wind and note carefully the weather during this interval. A reference to the table in page 133 will give him at a glance approximately the direction of the path or track of the centre. The directions in that table are only given to sixteen points, and are not intended to be assumed as exact. It is believed the table gives sufficiently nearly for the practical use of the sailor, the track of a cyclone in any case which he is likely to meet with.

It may be noted that there is no simple or satisfactory rule for determining approximately the distance of the centre of a cyclone by means of single observations such as can be taken on board ship.

The inner storm area of the intense cyclones of the Bay of Bengal is probably never less than 80 to 100 miles in diameter or greater than 400 or 500 miles. The rate at which the barometer falls, the rapidity with which the wind shifts, together with the force of the wind, and the swell and sky indications will usually tell the sailor whether a cyclone he meets with is a small or large one, whether he is approaching or entering the inner storm area or is still well outside of it, &c. Combining these facts with the above statement of the limiting magnitudes of the inner storm area of cyclones, he will be able to estimate approximately at what distance he is from the centre.

No satisfactory rule can be given enabling him to decide whether a cyclonic storm he is entering has an inner storm area of hurricane winds or not, and still less at what distance its outer edge may be from him. As already stated, the time of the year, the swell, sky appearances., &c., afford some indication. The only safe rule is to assume that any cyclonic storm in the May or October transition periods (*i.e.* from 1st May to 15th June and from 15th September to 15th December) is most probably a cyclone and to take precautions accordingly.

Usual tracks and probability of occurrence of cyclones and cyclonic storms in different months in the Bay of Bengal.—The following gives a brief summary of what is known from the experience of past years and the labours of the India and Bengal Meteorological Departments of the distribution of storms month by month in the Bay of Bengal.

January, February and March.—Cyclones or cyclonic storms are almost unknown in the Bay of Bengal in these months, and only occur under very exceptional circumstances and at very distant intervals.

April.—Cyclonic storms are of comparatively rare occurrence in the Bay of Bengal in April. They form either in the south of the Bay or in the Andaman Sea. Those which form in the Bay proper are generated to the west of the Nicobars or Andamans, and march (in at least three cases out of four) in a west or west-north-west direction to the Ceylon or Coromandel Coast. Those which originate in the Andaman Sea march northward to the Lower Pegu Coast. Storms are somewhat less probable in this month in the Andaman Sea than in the Bay of Bengal.

May.—Cyclonic storms are of comparatively frequent occurrence in the Bay during May (about two every three years). If they originate in the first fortnight of the month, the chances are about three to one, they will march in a westerly direction to the Coromandel coast; but if during the latter half of the month the chances are four or five to one, they will march northwards to the head of the Bay. It is also about an even chance that a storm forming in this month will be of great intensity (*i. e.* a cyclone).

June.—Cyclonic storms are of frequent occurrence in the north of the Bay in June. They usually form to the north of the 20° parallel of latitude, or quite at the head of the Bay. From one to two such storms may be expected every year. It is an even chance whether they pass in some northerly direction into Bengal or in some westerly direction across Orissa. Their chief feature is the strong westerly or south-westerly winds or gales in their southern quadrants. It should also be noted that two out of three advance across the north-west angle of the Bay immediately to the south of the entrance to the Hooghly, and hence they are very trying to shipping leaving the Hooghly at such times.

July.—In July storms only occur in the north of the Bay. They are of comparatively frequent occurrence, an average of two or three occurring in every year. They usually march in a west or west-north-west direction across the north-west angle of the Bay to the Orissa coast. The chances of a storm forming at this time marching in this direction are about 10 to 1. They are frequently feeble, but in about one case out of three they give rise to strong westerly and south-westerly gales at the head of the Bay, in which the force of the winds exceeds 9. As they almost invariably cross the north-west angle of the Bay, and hence advance across the track of vessels leaving the Hooghly, outward-bound vessels, unless fully prepared to encounter a severe storm of this kind, should not leave the river Hooghly when the storm signals are hoisted, and should remain in the river until the lowering of the signals.

August.—Cyclonic storms are almost of as frequent occurrence in August as in July. Five out of every six form to the north of latitude 20°. Hence the chief feature of the storms of August is strong westerly and south-westerly gales at the head of the Bay, and the shift of wind is rarely large enough to indicate their cyclonic character except in the north-west angle of the Bay. The storms of the month occasionally advance northwards across the Bengal coast, but more frequently in a west or west-north-west direction across the Orissa or Ganjam coast. The chances based on previous experience that a storm which forms in the month will advance in a westerly direction are two to one, and that it will advance north into Bengal are one to two. As the great majority of these storms advance across the track of vessels leaving the Hooghly, captains of vessels about to proceed to sea from Calcutta when the signals are hoisted should, unless they are prepared to encounter strong winds and a very heavy sea, if possible, remain in the river until the storm has advanced landwards.

September.—Cyclonic storms are as frequent in the Bay during September as in July and August, an average of two occurring every year. These cyclonic storms, however, form, as a rule, further south than in the previous two months, but usually to the north of latitude 17°. The chances are four to

one that the centre of a storm which forms in September will advance in a westerly direction to the north-west coast between Balasore and Coconada. About one storm out of five advances in a northerly direction into Bengal. The great majority of these storms are of small intensity, and resemble the storms of July and August in general character and in the strength of the westerly and south-westerly winds (as compared with the north-easterly and northerly winds). Under exceptional conditions, the chief of which appears to be the earlier retreat of south-west monsoon than usual from Northern India, these storms are of great intensity and violence, and accompanied with hurricane winds. Hence cyclones are of very occasional occurrence in September, and are most probable in the last fortnight. They form in the centre of the Bay, and the chances are about equal that they will advance in a north-west direction to the Bengal coast, or in a westerly direction to the coast of the Circars.

October.—Cyclonic storms occur less frequently in the Bay in October than during any of the five preceding months. They are of very rare occurrence in the Andaman Sea, and rarely, if ever, form to the north of latitude 20°. They may originate in any other part of the Bay, but form most frequently in the centre of the Bay between the Andamans and the coast of the Circars. If a storm forms in this month, the chances are probably about one to two that it will develop into a severe cyclone. The chances are about even that if a storm is generated in this month it advances westwards to the coast of the Circars, and if it does so, the chances are also about even that it is a feeble or a severe storm, or in other words a cyclonic storm or a cyclone. The chances are about one to three that if a storm forms in this month it will advance northwards to Bengal or Orissa, and, if it does, the chance that it will be a severe storm, or a cyclone is at least two to one. The chances that if a storm forms it will advance to the Madras coast are also about one to three, but if it does, the chances that it will be a severe storm are probably about even.

November.—Cyclones may form in any part of the Bay and Andaman Sea to the south of latitude 16° in the month of November. Two out of three storms which originate in this month form in or to the south of latitude 12°. At least one storm may be expected every year in this month. The chances that a storm in November will be a cyclone are about two to one. If a storm forms, the chances that it will advance to the Coromandel coast are about two to one. About one storm out of three that form advances to the coast of East Bengal or Arakan. The part of the Bay which is most free from cyclonic storms in this month is the north-west angle of the Bay and the coast from Saugor Island to Vizagapatam. On the other hand, the north-east coast of the Bay is more liable to cyclones in this month than in any other month of the year.

December.—Storms are of comparatively rare occurrence in the month of December. No storm has been known to form in the Andaman Sea in this month. Storms occasionally form in the south or south-west of the Bay of Bengal between the Ceylon coast and Andamans. The chances are nearly two to one that if a storm occur in this month it will be a violent cyclone. It is also almost a certainty that a storm which forms in this month will advance in a west-north-west direction to the Coromandel coast between Madras and Negapatam.

Hence they are chiefly dangerous in the area between the East Ceylon coast and the Coromandel coast.

Some practical hints for the benefit of vessels navigating the Bay of Bengal.

When the sailor in the Bay of Bengal has ascertained the bearing and track of the centre of a cyclonic storm in the Bay of Bengal he has then to determine what action he will take in order to avoid it so far as possible. The following hints are given chiefly by way of suggestion, and not as rules.

In the case of a steamer there is no doubt that, if the earlier indications of a cyclone be carefully observed, and the position and path of the cyclone be judged with approximate correctness, it is nearly always possible to avoid entirely the inner storm area of a cyclone and to pass out or keep outside of the outer storm areas.

It would be out of place in the present book to attempt to give precise instructions how to handle a vessel in order to avoid a cyclonic storm, or cyclone in the Bay of Bengal.

In drawing it up, it has been assumed throughout that it is desirable to state and explain every indication by which the bearing, probable distance and track of the centre of a storm can be estimated and also its intensity, especially so far as it depends upon the month or period of its occurrence. If the sailor has ascertained these points when he is on the outskirts or outer storm area of a storm, he ought to be qualified to decide which is the best course to take in order to avoid, so far as is possible, the chief dangers to which he is exposed; as, for example, passing into the inner storm area, encountering the hurricane winds of a cyclone or the fierce westerly gales of a cyclonic storm of the rains, or of being carried by the wind and current of an approaching storm against a lee shore.

Much depends upon whether he is in charge of a steamer or a sailing ship, and whether the vessel is large and well found, and also upon his judgment of the position of his vessel with respect to the coast, as well as to the centre, and upon the strength of the currents produced by the storm.

The object of the sailor ought to be—

1st—to avoid entering the inner storm area;

2nd—if he finds himself involved in the dangerous semicircle, and more especially in the right advancing quadrant, to use every effort to avoid being carried in front of the advancing centre.

He should bear carefully in mind that the right advancing quadrant is the most dangerous, and the left advancing quadrant the least dangerous quadrant in the cyclones and cyclonic storms of the Bay.

He should also remember that in storms near the head of the Bay, or which advance to the head of the Bay, the strongest winds appear to be experienced in the south-east quadrant, or to the south and south-east of the storm centre, and that these winds extend to very considerable distances from the centre, and finally merge into the intensified south-west winds which prevail in the south of the Bay. In the case of cyclones or cyclonic storms approaching the Coromandel coast, the strongest winds are usually experienced to the north and east

of the storm centre and usually extend to much greater distances to the north than to the south. The right advancing quadrant is very dangerous in the case of these storms.

He should, as soon as he perceives any indications of a storm, and more especially the occurrence of squalls with increasing frequency and strength, use every available indication to judge of its position and character, and not wait until his barometer begins to fall rapidly and winds have increased to the force of a heavy or hard gale, as he will then almost certainly be entering the inner storm area of a cyclone.

He should, even if in command of a well-found steamer, not attempt to pass round a cyclone in the advancing semicircle, unless he has the strongest evidence that the cyclone is at such a distance that he can get well into the left advancing semicircle, or manageable semicircle before the storm passes him. It is always attended with risk, and cyclones in the Bay are sometimes of very small diameter and advance very rapidly, so that errors of judgment in the distance of a cyclone are very possible. A ship ought on no account to attempt it, except as a last resort.

Hence the advisability of steamers and ships about to proceed to sea from Calcutta when a storm is approaching the Bengal, Orissa or Circars coast, delaying their voyage and staying at Diamond Harbour or in the river until the cyclonic storm has reached land. It is very difficult to estimate correctly the intensity of an approaching storm, and hence the only safe and prudent course for vessels which can only pass out of the river by proceeding at once into the most dangerous quadrant of a cyclone, is to wait until all danger is past by the advance of the storm inland.

In all cases a ship or steamer should be manœuvred, so as to increase her distance from the centre, as soon as she enters the outer storm area. A steamer can, of course, except under very unusual circumstances, do this, if the storm centre and track be ascertained early and she have sea-room.

If a steamer is in the open sea and finds herself in the dangerous semicircle, she should generally steam slowly against the wind with the wind on her starboard quarter.

In the case of a vessel lying at anchor on the Madras coast or proceeding along that coast, if the centre of severe cyclonic storm be approaching directly towards that part of the coast, she ought especially to avoid passing into the right-hand semicircle and proceed south or south-south-east, so as to avoid the storm. The winds near the coast and the sea in the left advancing quadrant are in this case comparatively light, and there is little or no danger from currents. If in the right advancing quadrant, the commander of the vessel ought to judge of his position as early as possible and proceed well out into the open and keep as far north as is advisable considering his proper course, and then, if proceeding southwards, pass round the storm in the east quadrant. In this case delay in taking the proper action is especially dangerous.

In the case of a sailing ship the following are the rules usually given.

If the vessel be in the right-hand semicircle of a cyclone or cyclonic storm, heave-to on the starboard tack. If in the left-hand semicircle run, keeping the

wind on the starboard quarter, if possible. When the squalls decrease and the barometer rises, if necessary, heave-to on the port tack if it is desired not to proceed too far from the proper course.

It is sometimes not expedient to run in the manageable or left-hand semicircle, in which case it is usual to heave-to on the port tack.

It should be especially remembered that the south-west winds are always intensified in the south of the Bay during the existence of a cyclone or cyclonic storm in the north of the Bay. The barometer at this stage gives practically no indication of the distant storm. But, on approaching the outskirts of a storm in the Bay from the south, the squalls begin to increase in intensity and frequency, and in that case it is advisable to exercise great caution in running up the Bay, as in many cases in recent years where this caution has not been exercised vessels have been carried into the inner area and suffered severely.

It should be carefully noted that these suggestions are based on the information supplied in recent years to the meteorological office by ship-masters. Sailors should, in utilising any portion, carefully exercise their own judgment and remember Piddington's observation that in such matters "absolute rules are all nonsense."

Government of India Central Printing Office.—No. 85 Meteo.—3-1-90.—6502.

CUR I " NAL OSCILLATION OF
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rrom Lat. 0 10 Long. 80 to 90 E.

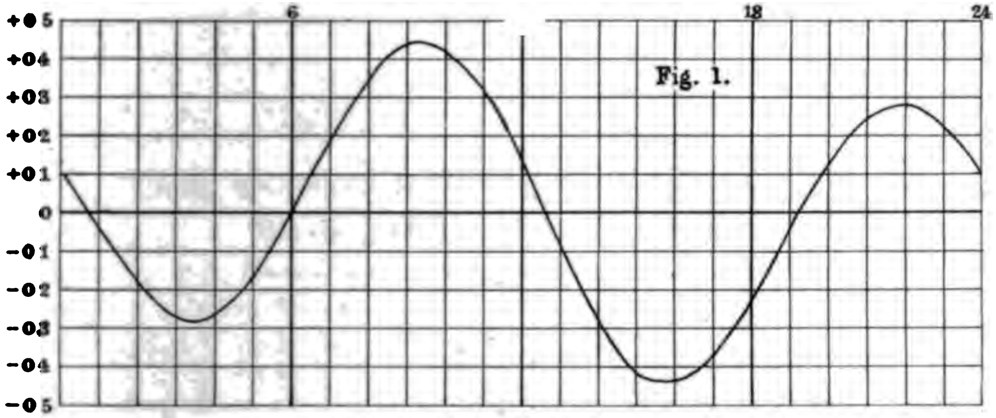


Fig. 1.

CURVE SHEWING MEAN DIURNAL OSCILLATION OF
BAROMETER IN BAY OF BENGAL.

From Lat. 10 to 20 N. and Long. 80 to 90 E.

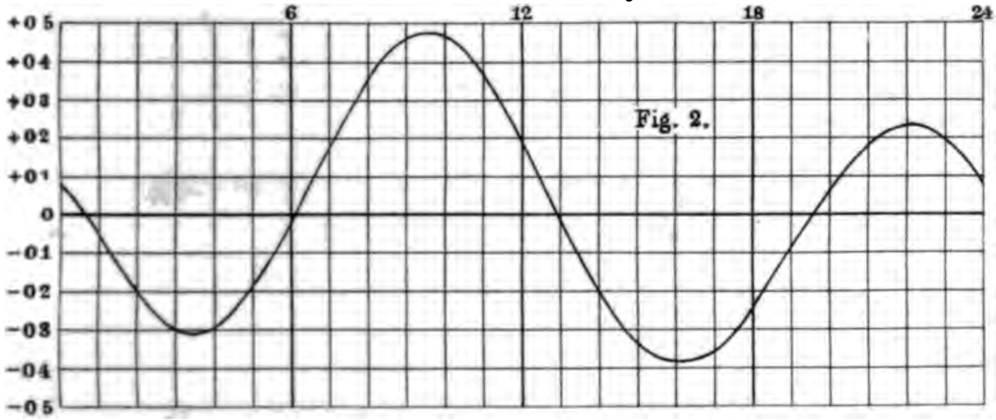


Fig. 2.

CURVE SHEWING MEAN DIURNAL OSCILLATION OF
BAROMETER IN BAY OF BENGAL.

From Lat. 0 to 20 N. and Long. 90 to 100 E.

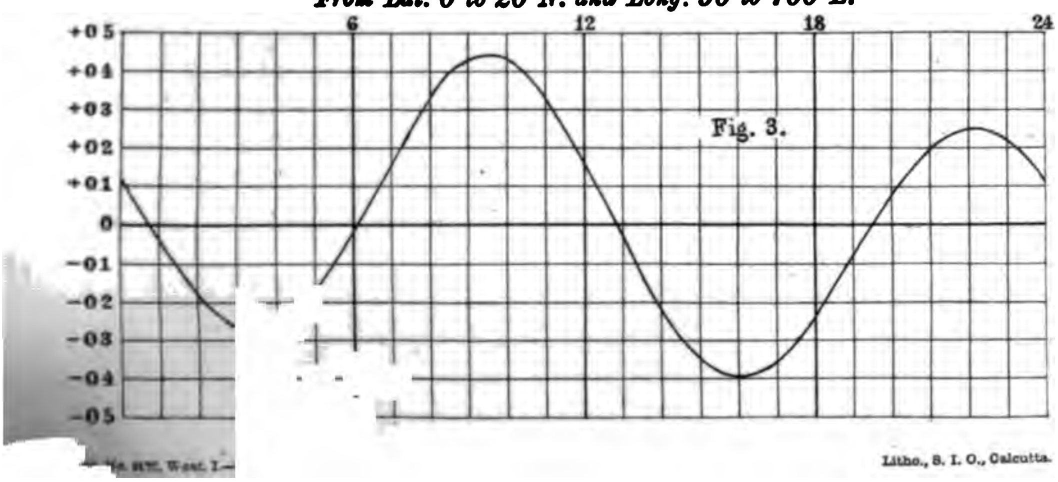
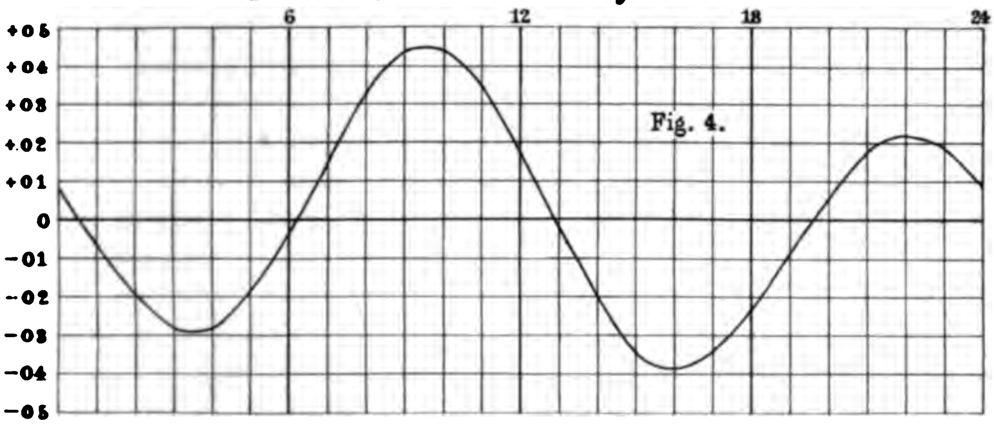


Fig. 3.

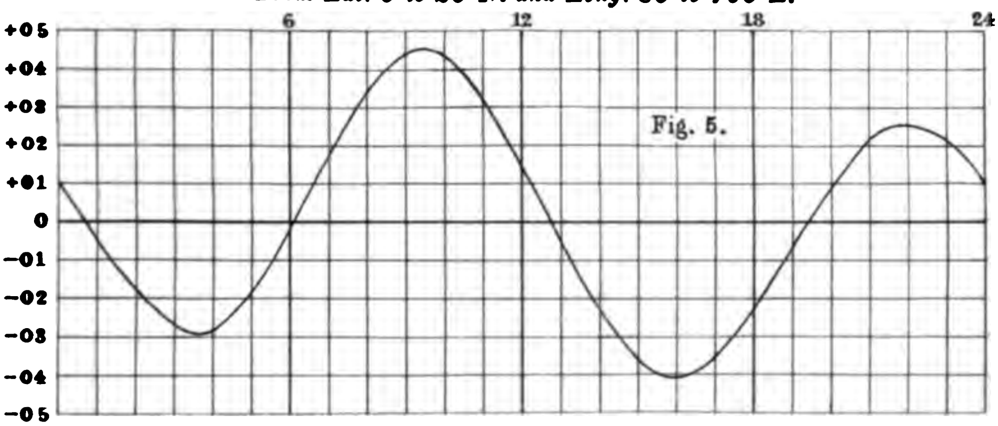
CURVE SHEWING MEAN DIURNAL OSCILLATION OF BAROMETER IN BAY OF BENGAL.

From Lat. 10 to 20 N. and Long. 90 to 100 E.



CURVE SHEWING MEAN DIURNAL OSCILLATION OF BAROMETER IN BAY OF BENGAL.

From Lat. 0 to 20 N. and Long. 80 to 100 E.



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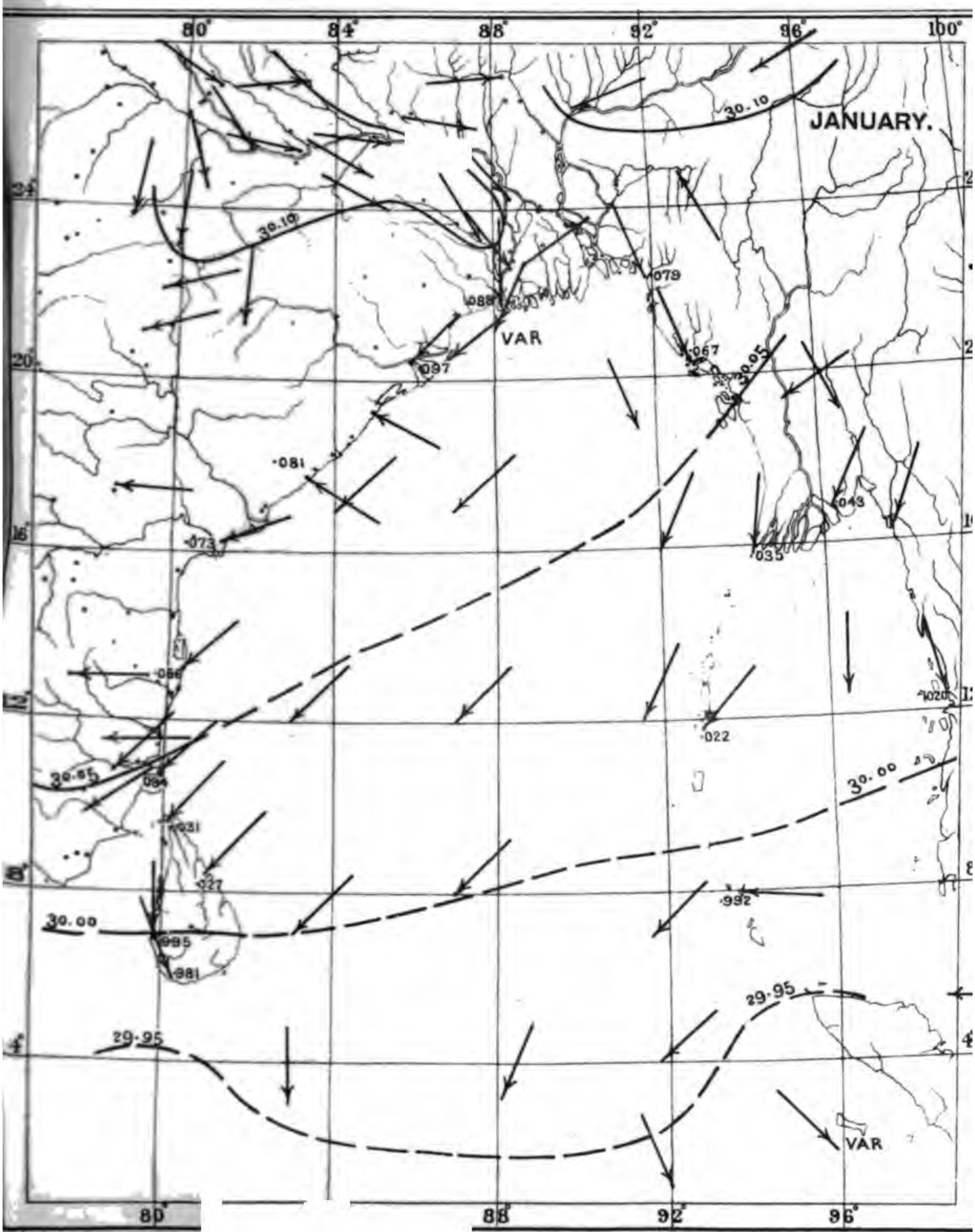
MEAN 8 A. M. BAROMETRIC HEIGHT AND MEAN DAILY WIND DIRECTION FOR MONTH OF JANUARY IN BAY OF BENGAL.



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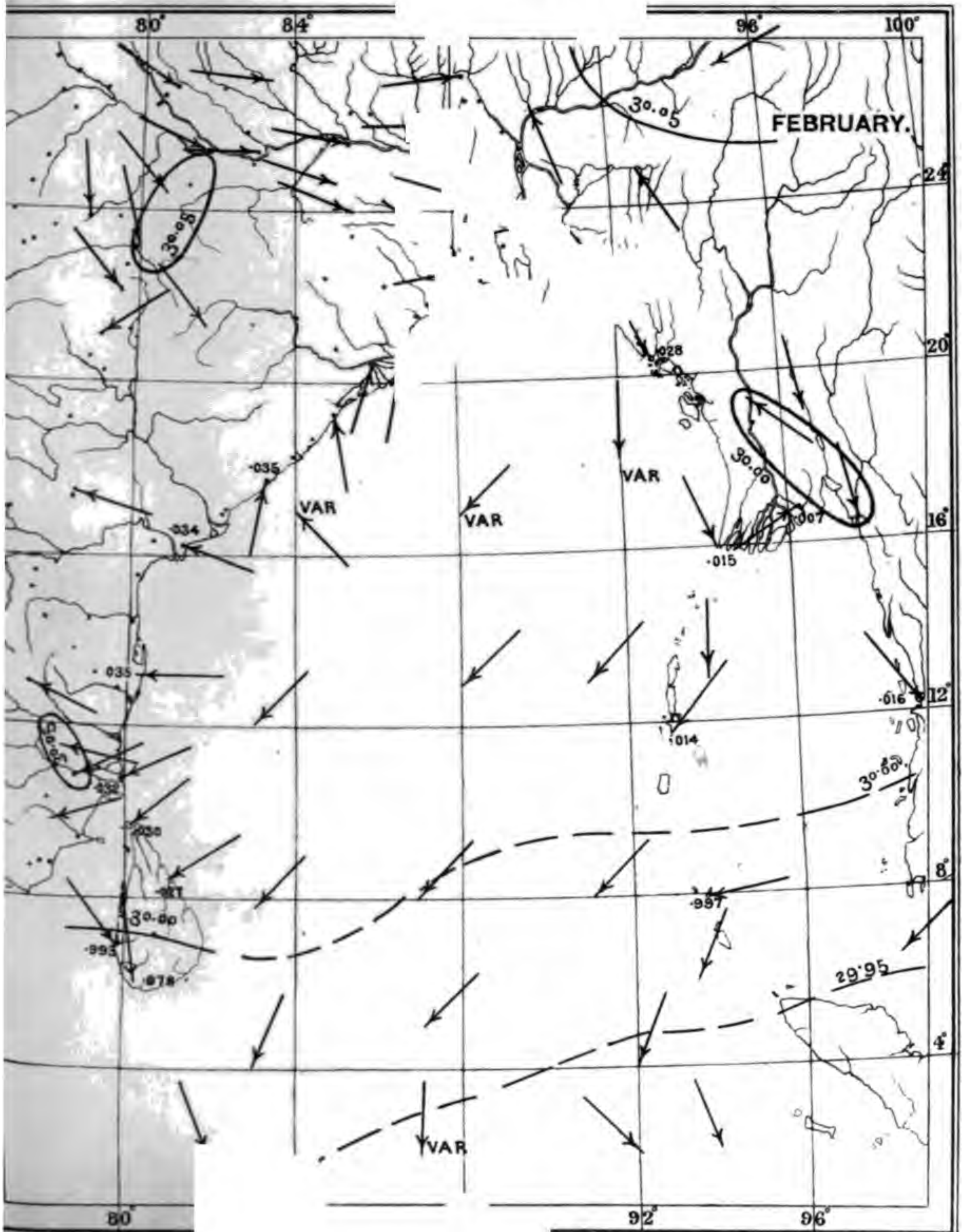

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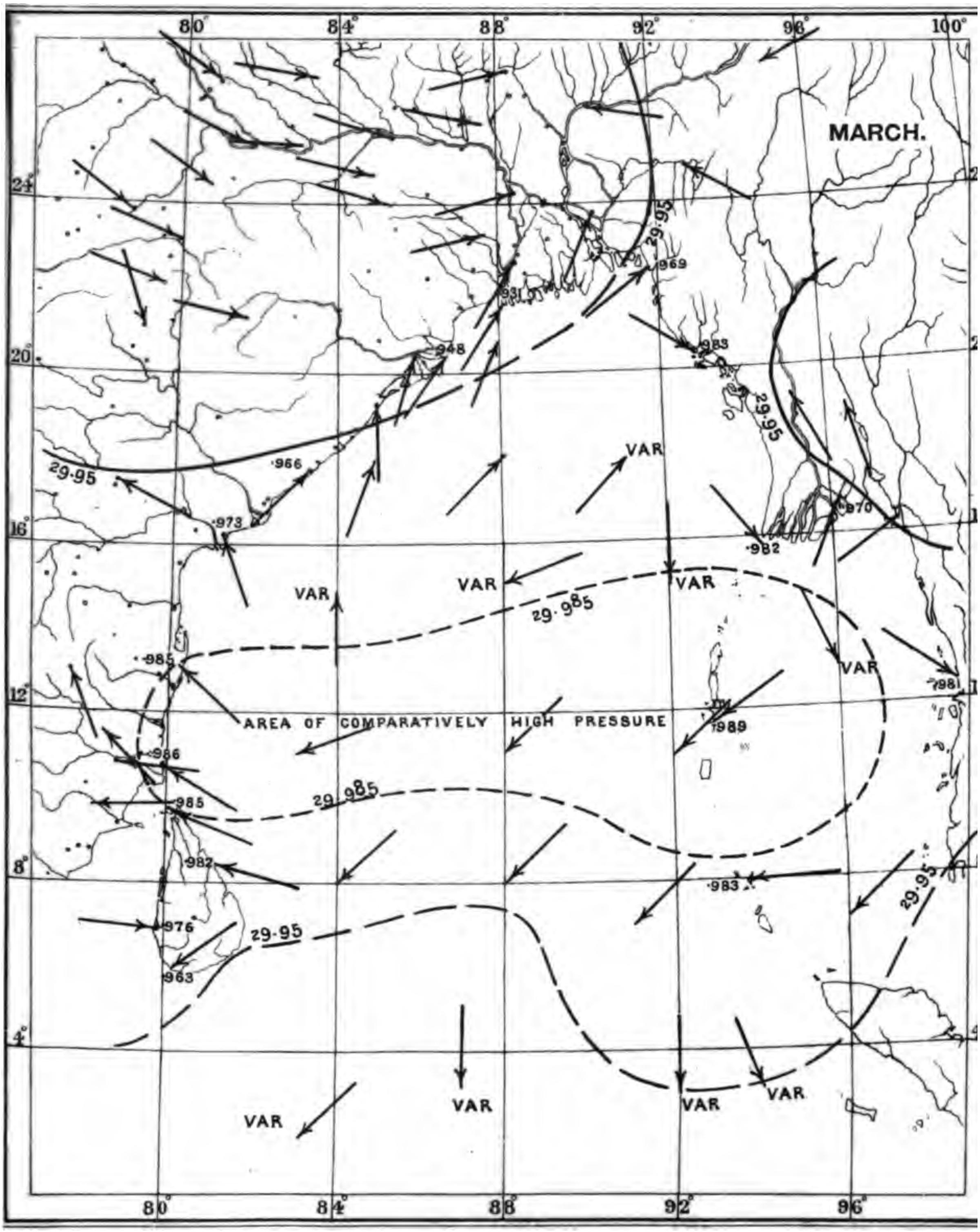

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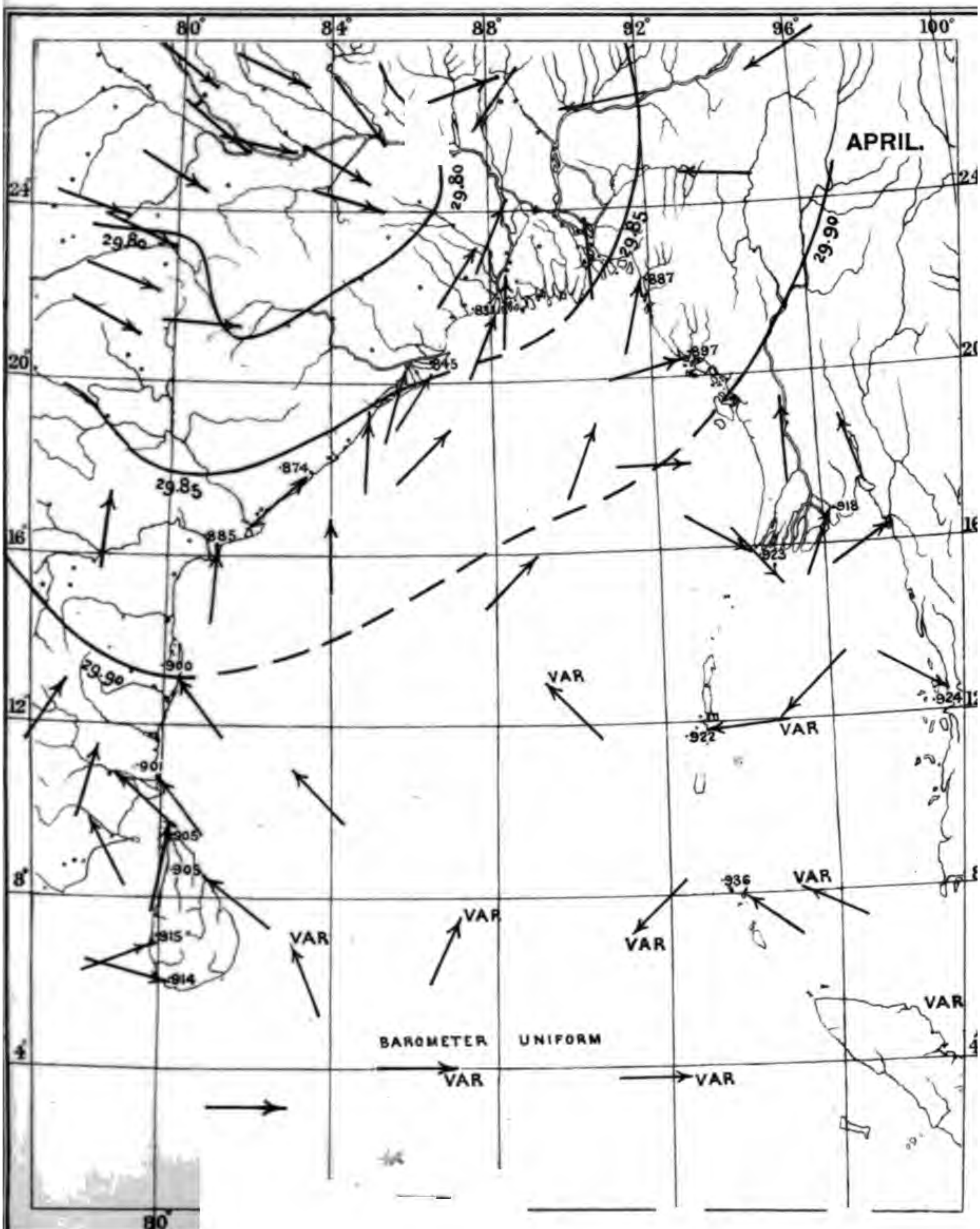
MEAN 8 A. M. BAROMETRIC HEIGHT AND MEAN DAILY WIND DIRECTION FOR MONTH OF APRIL IN BAY OF BENGAL.



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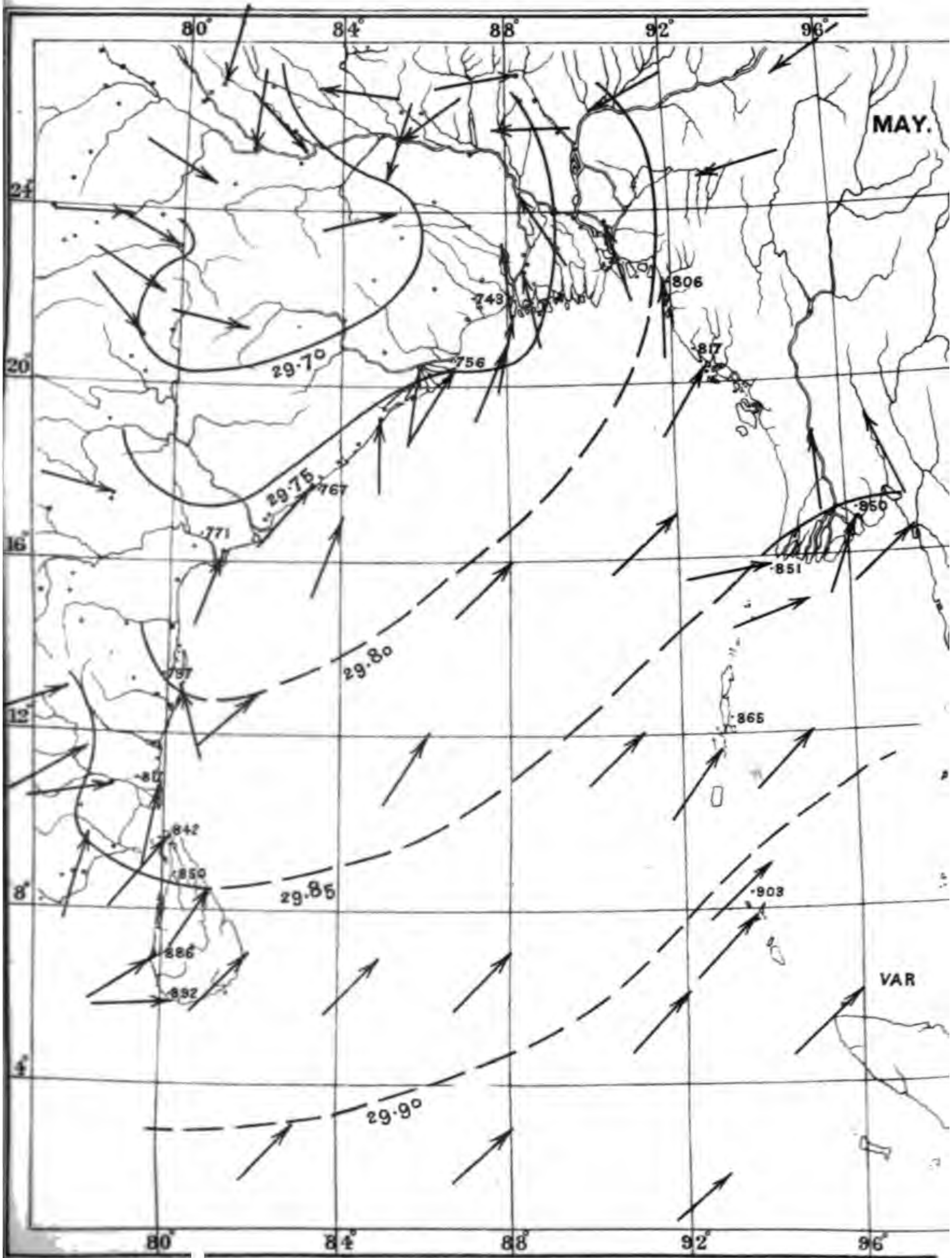
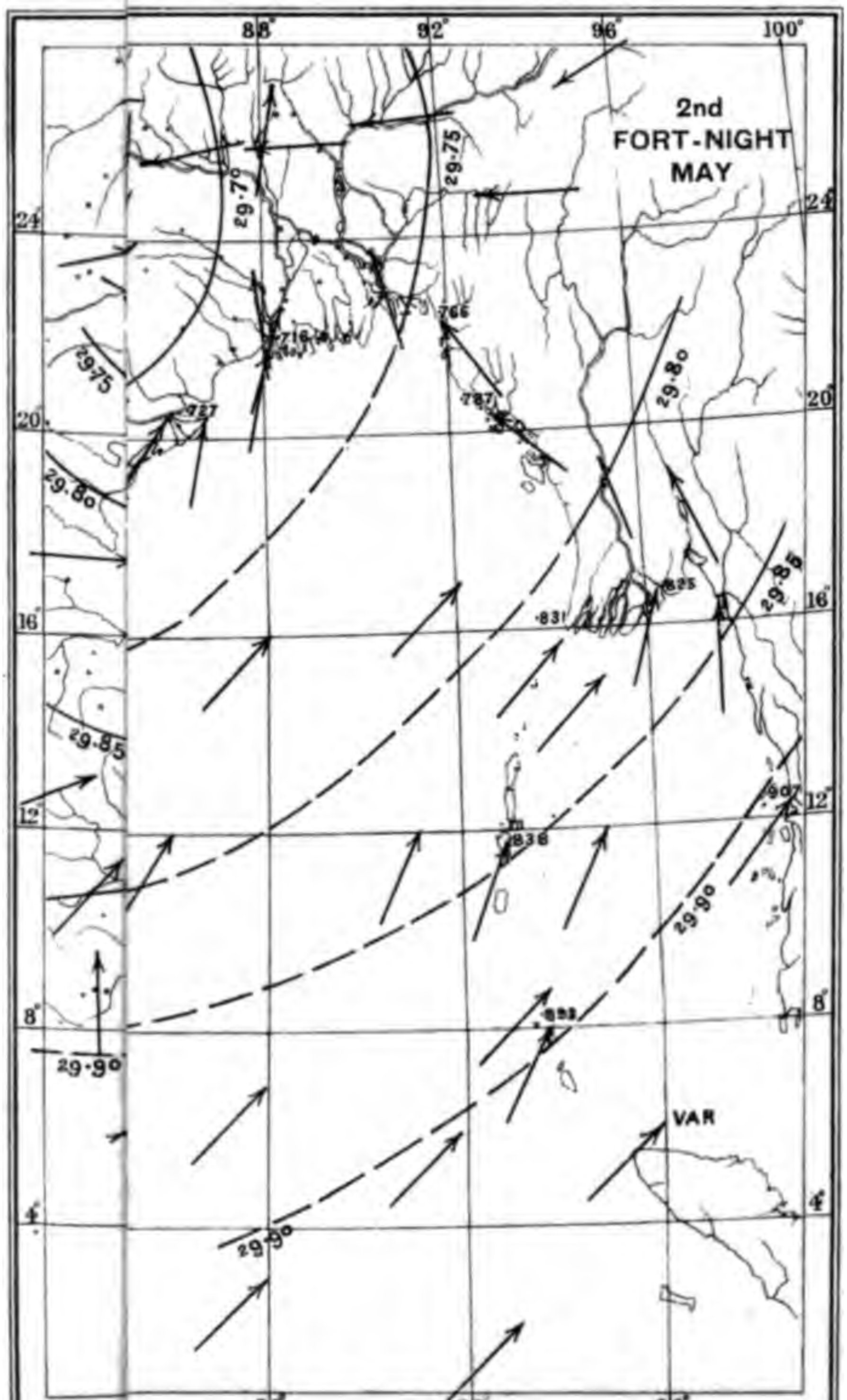


NIGHT OF MAY IN BAY OF BENGAL.



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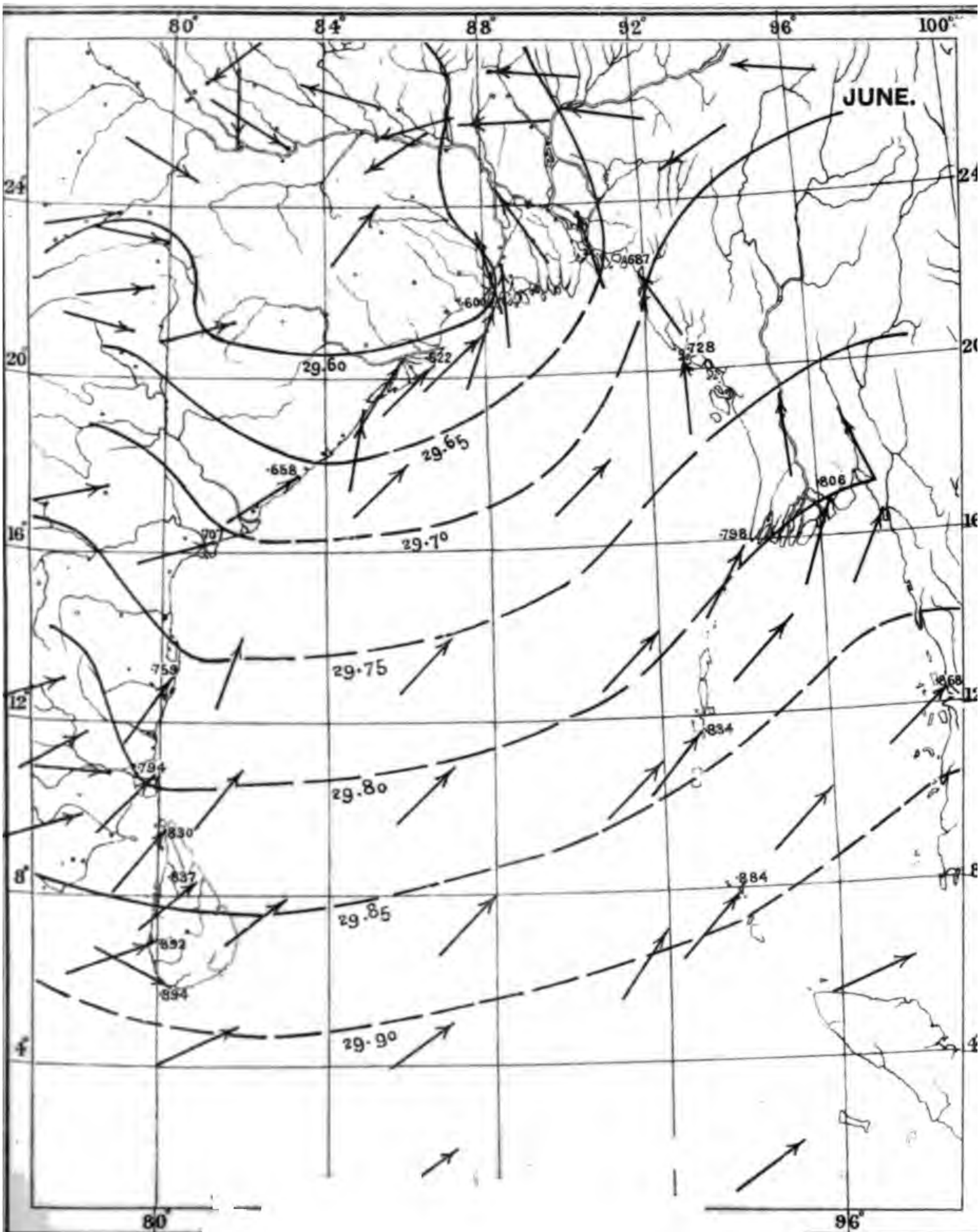

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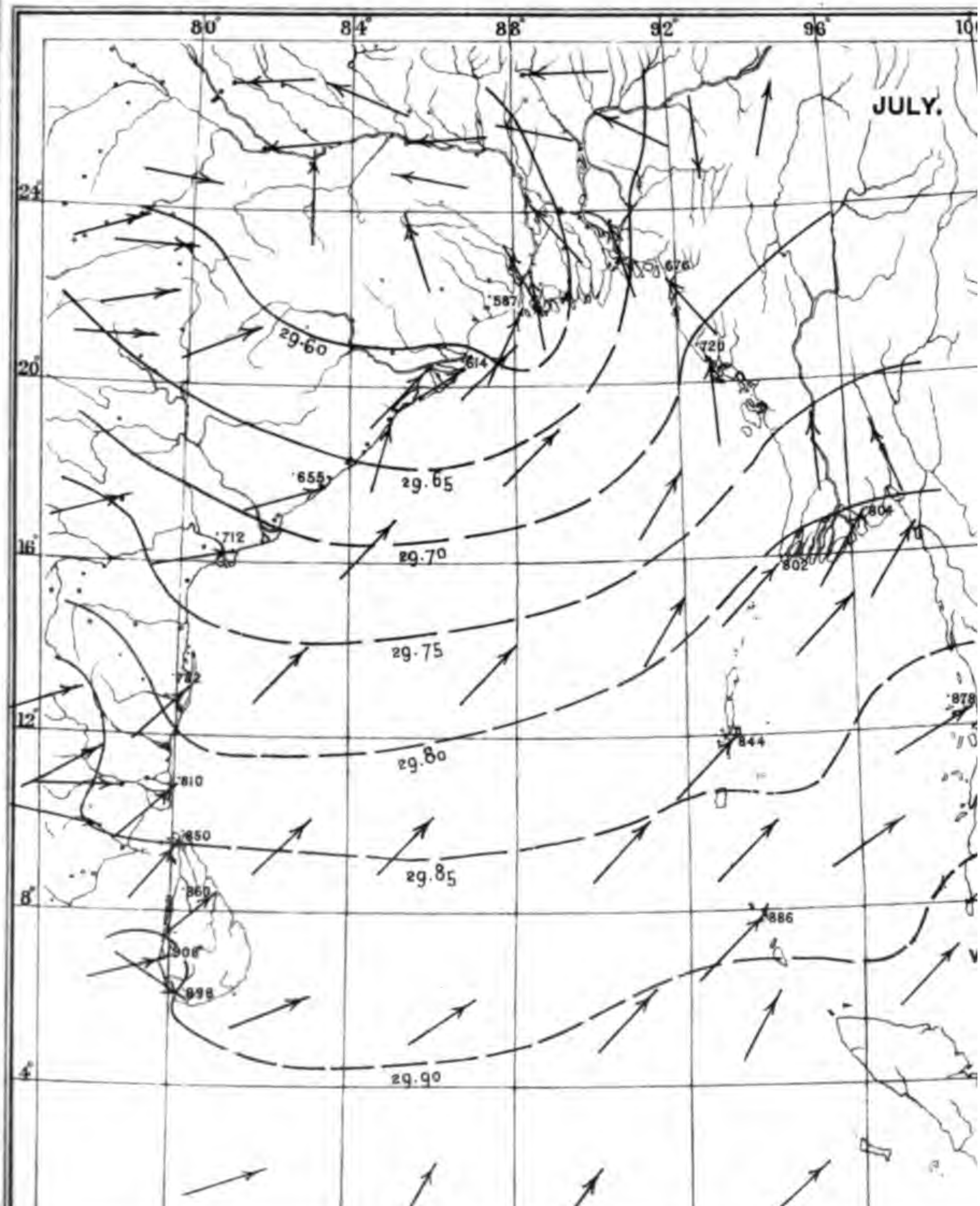

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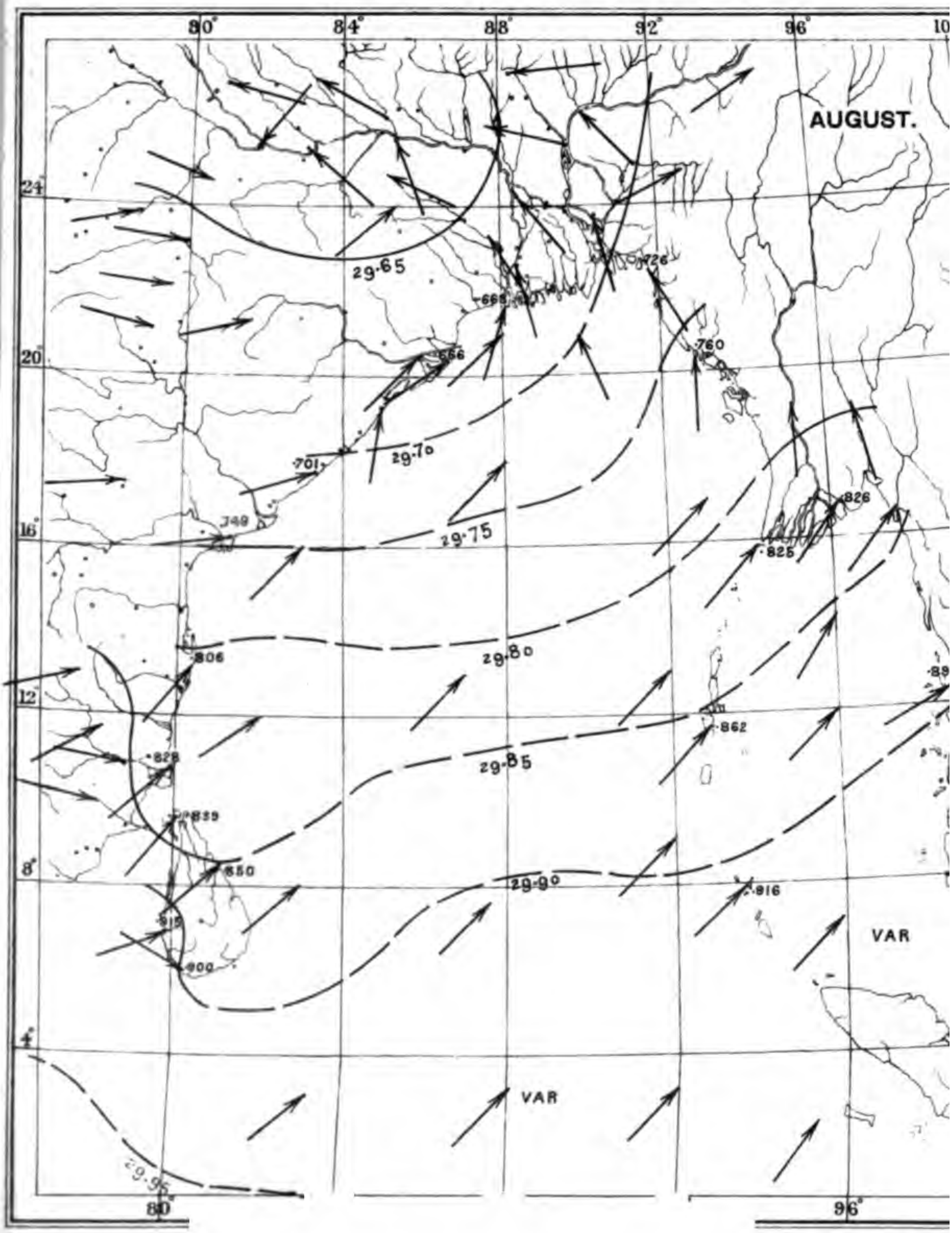
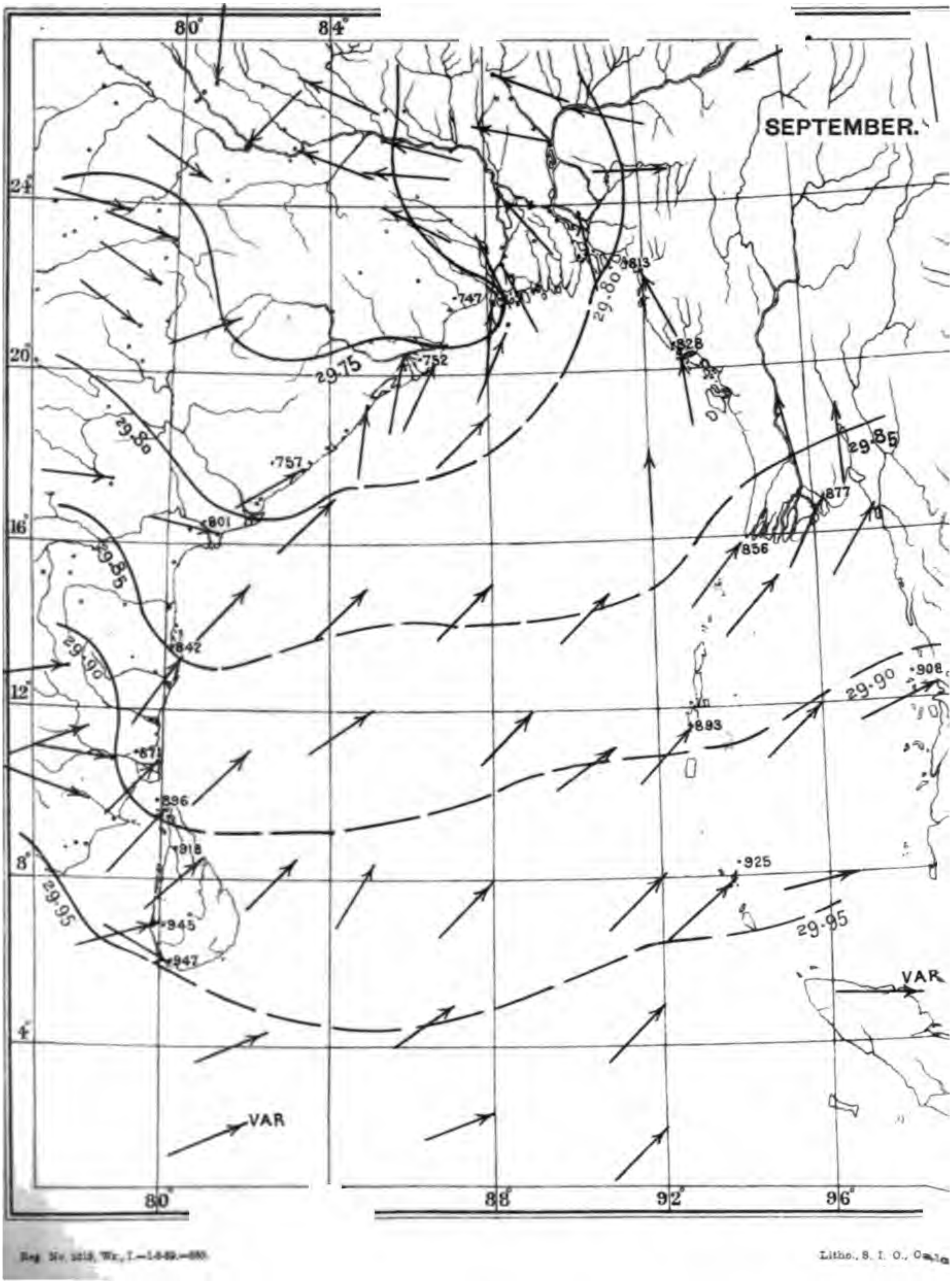


MEAN 8 A. M. BAROMETRIC HEIGHT AND MEAN DAILY WIND DIRECTION FOR MONTH OF SEPTEMBER IN BAY OF BENGAL.



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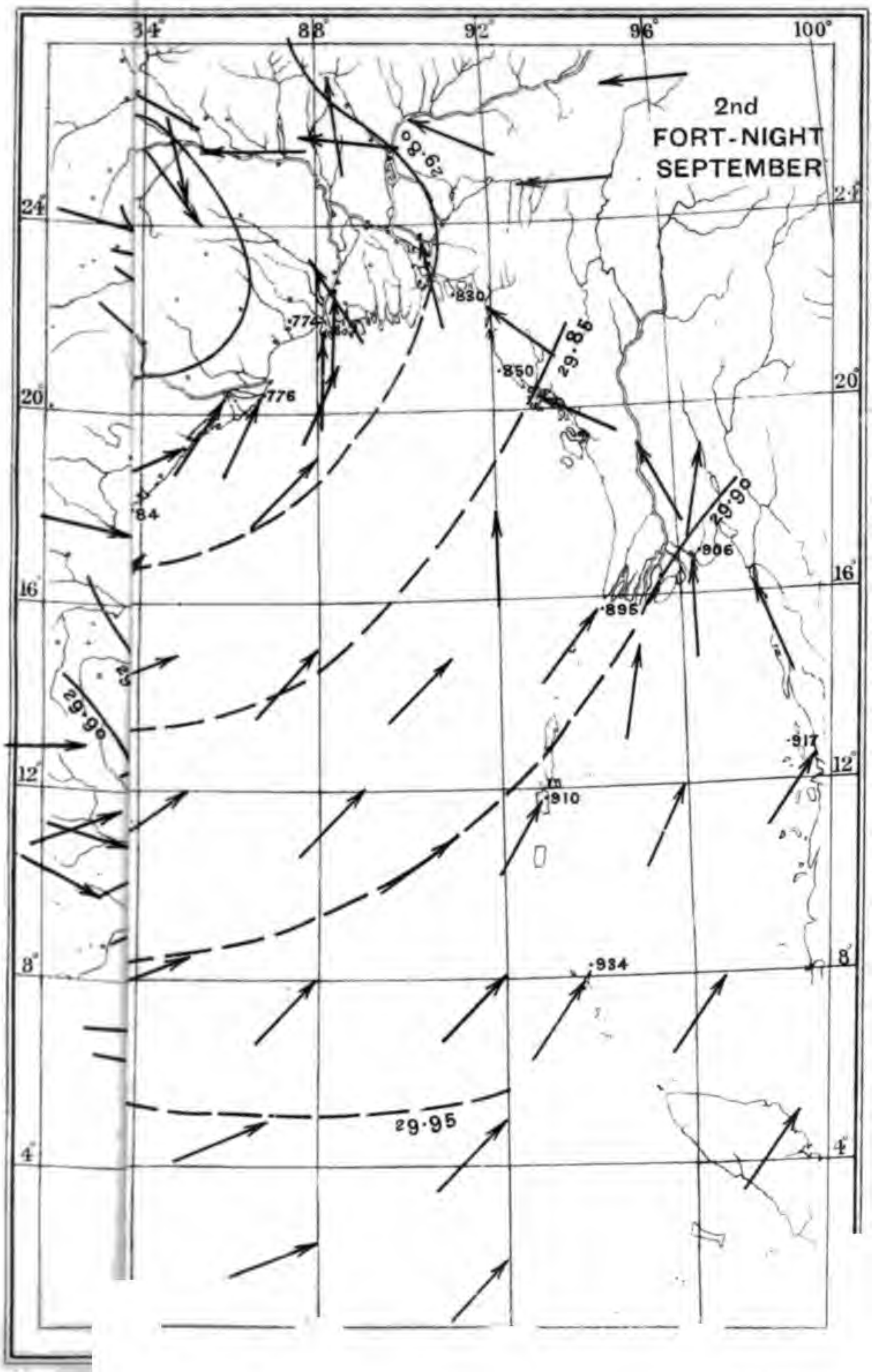
NIGHT OF SEPTEMBER IN BAY OF BENGAL.



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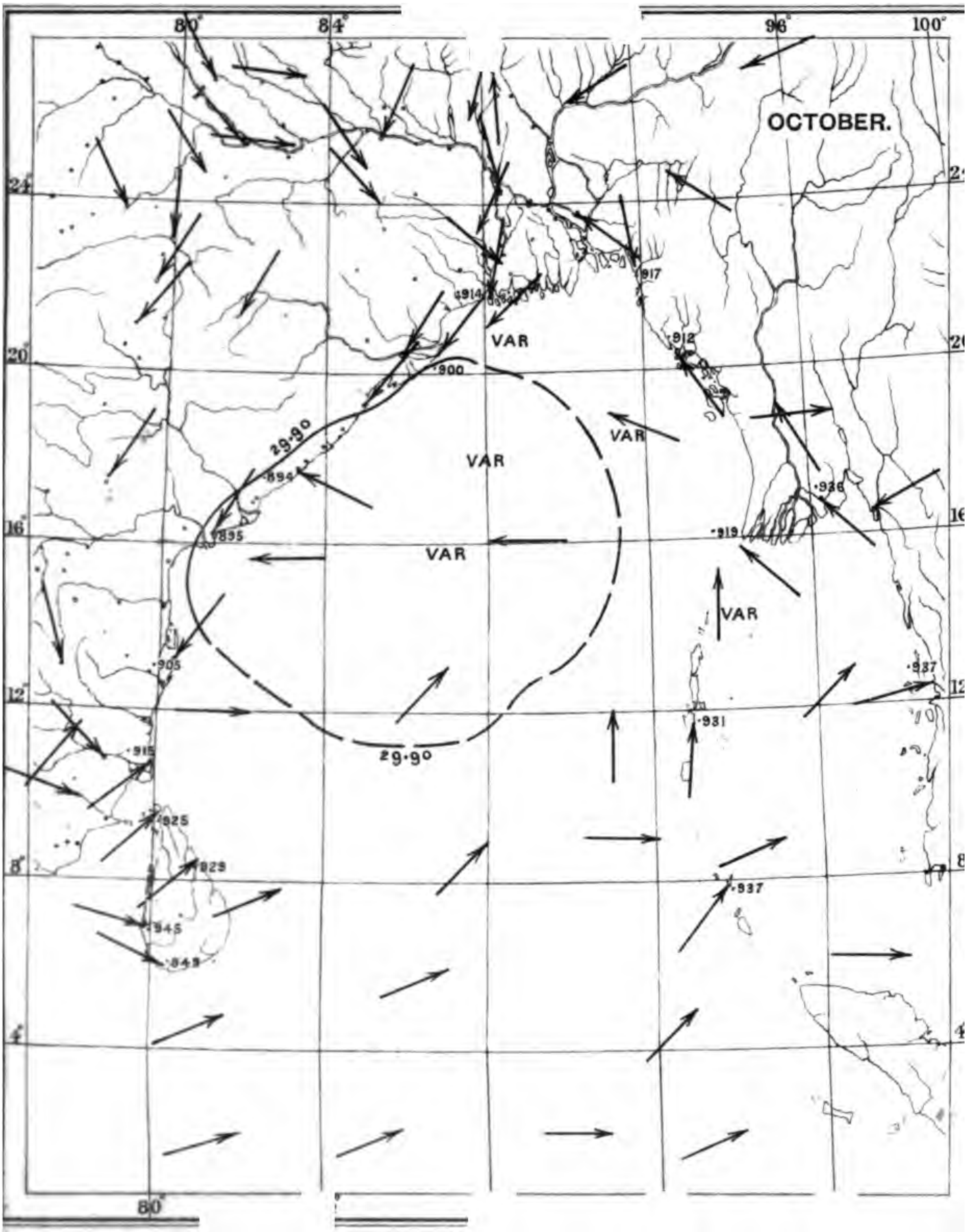

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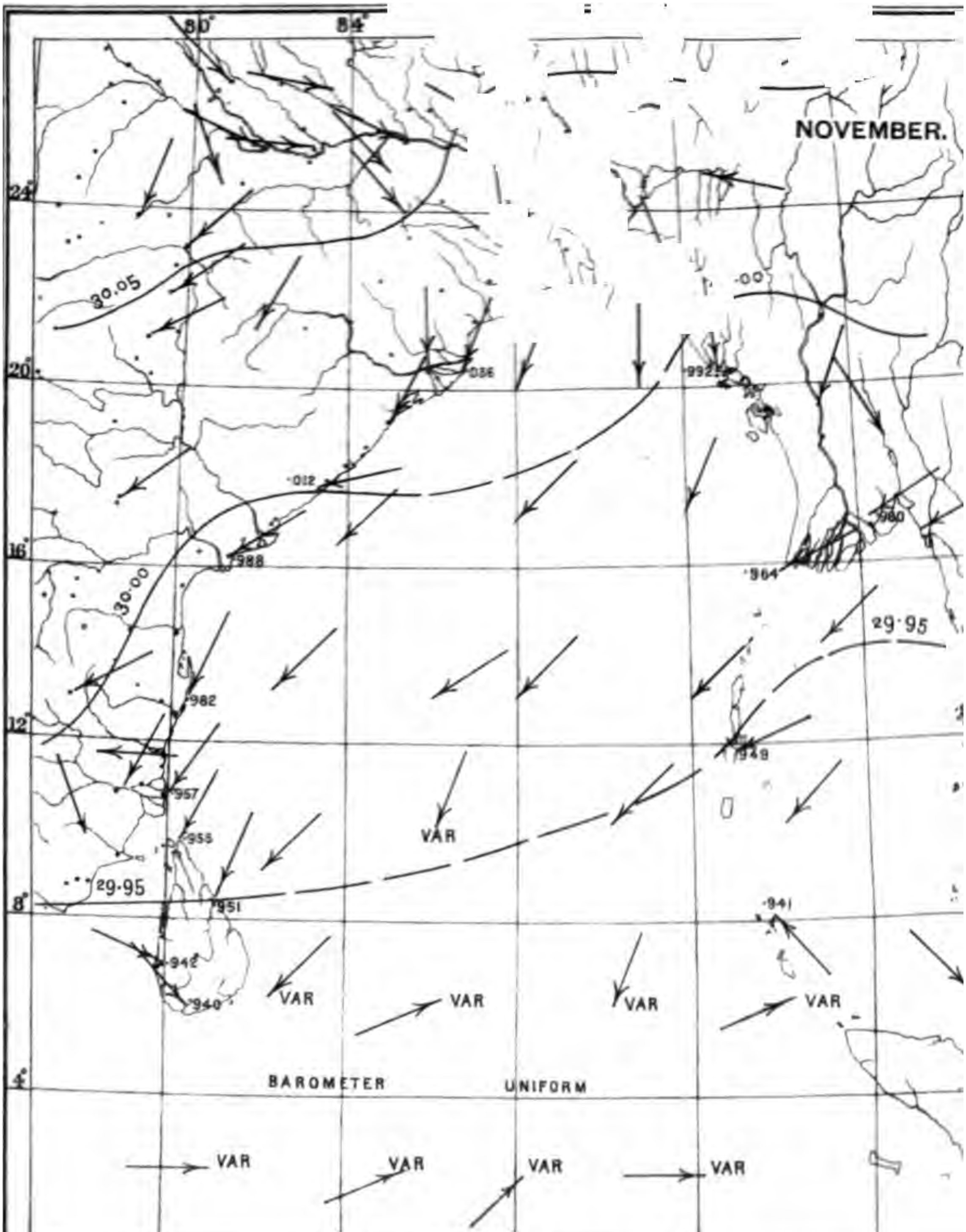

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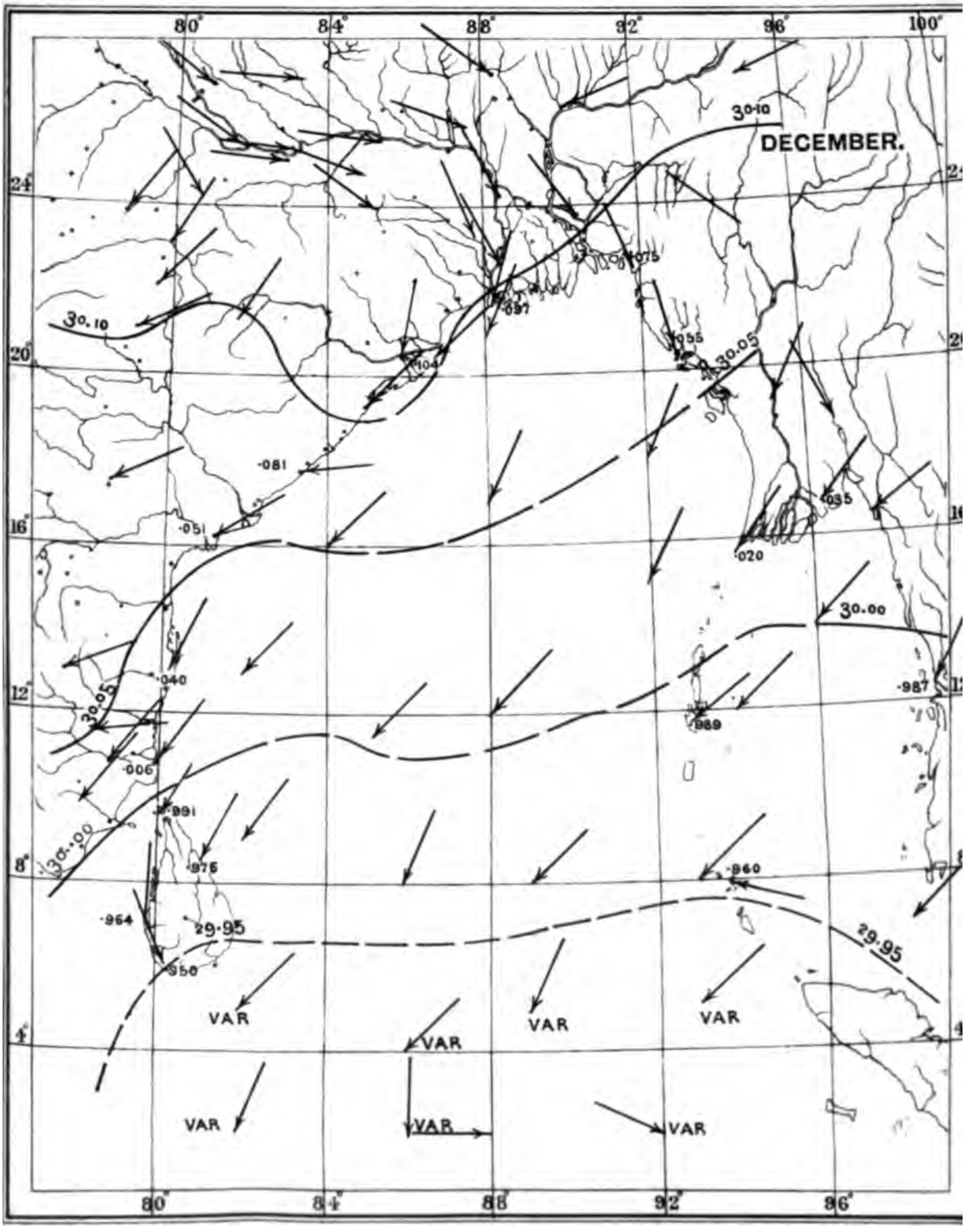

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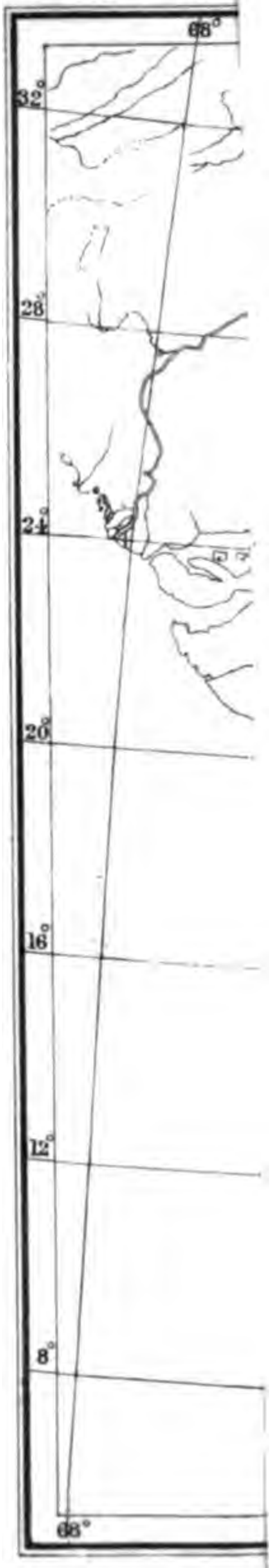

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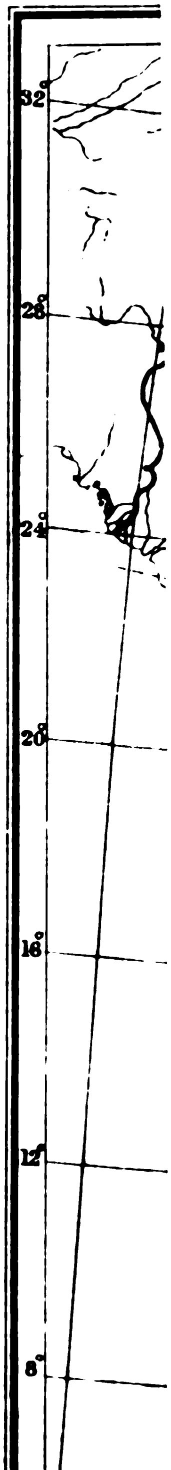

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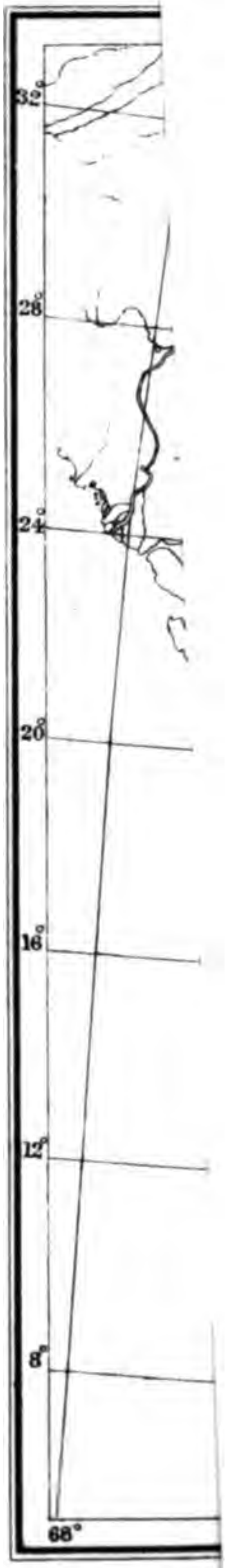

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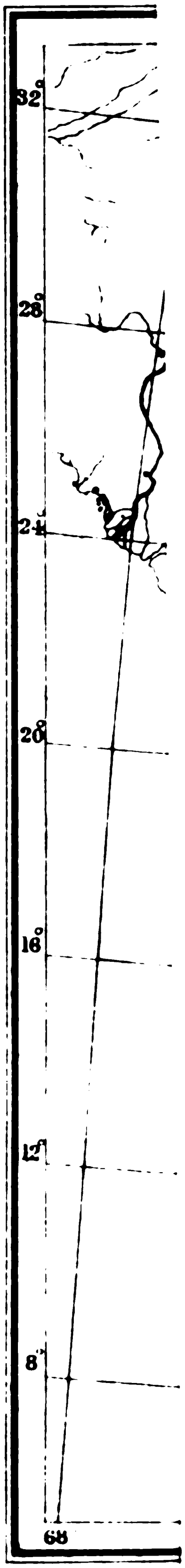

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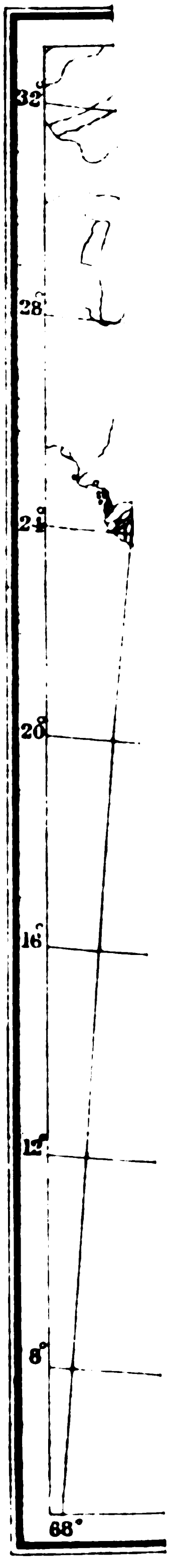

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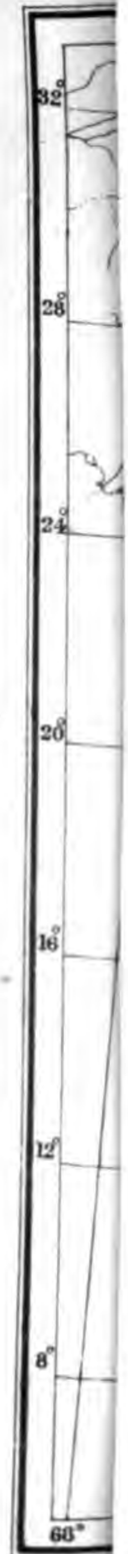
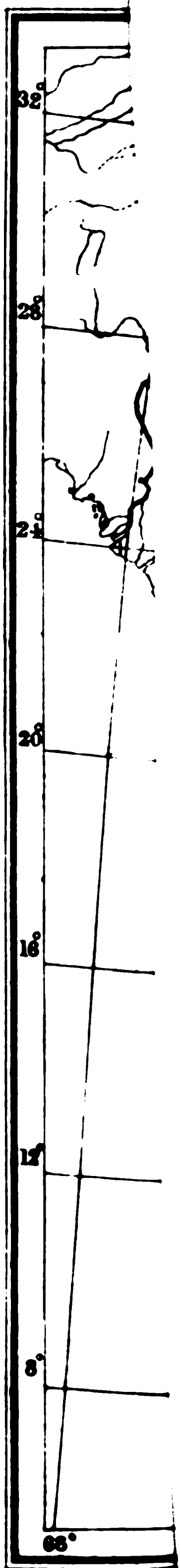


Eng. &c.

Bay of



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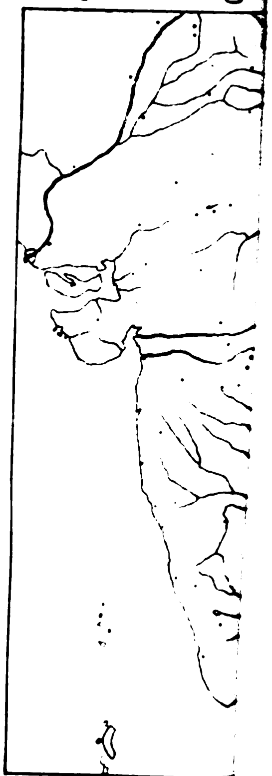
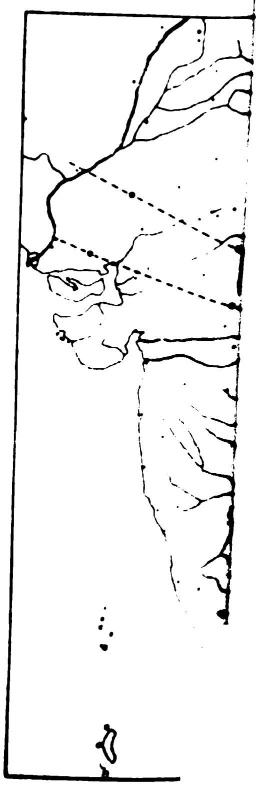
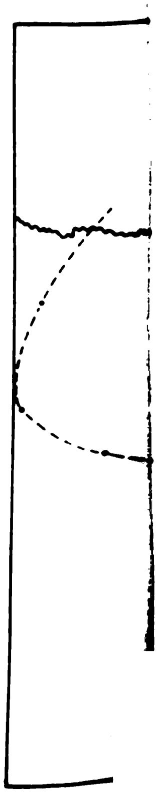
Bay of Benga





Reg. No. 2941



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No. 2818, Wt. I.

CHART SHOWING PLACE OF ORIGIN OF 109 CYCLONIC STORMS OR CYCLONES WHICH HAVE FORMED IN THE BAY OF BENGAL DURING THE ELEVEN YEARS 1877 — 87.

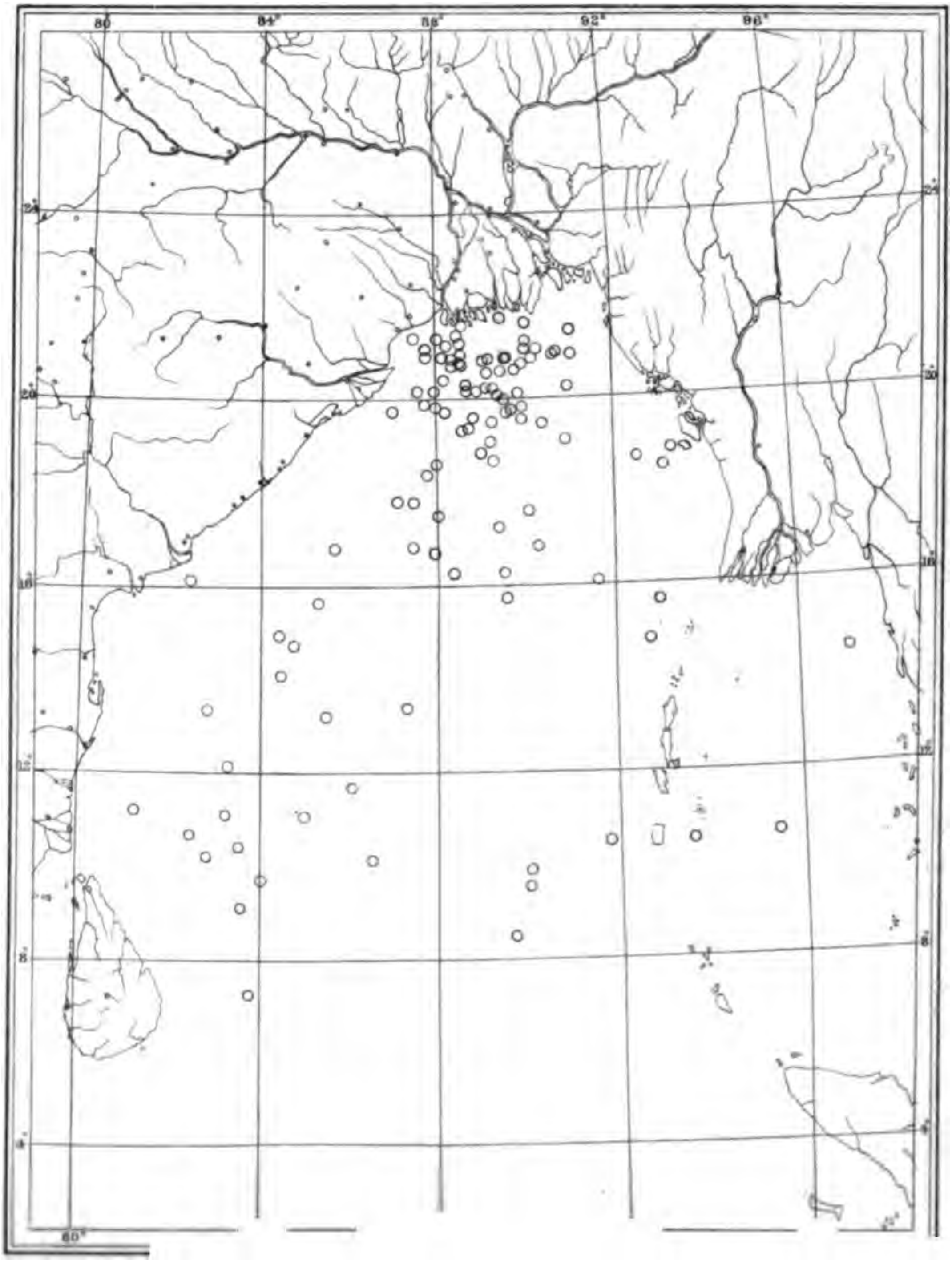
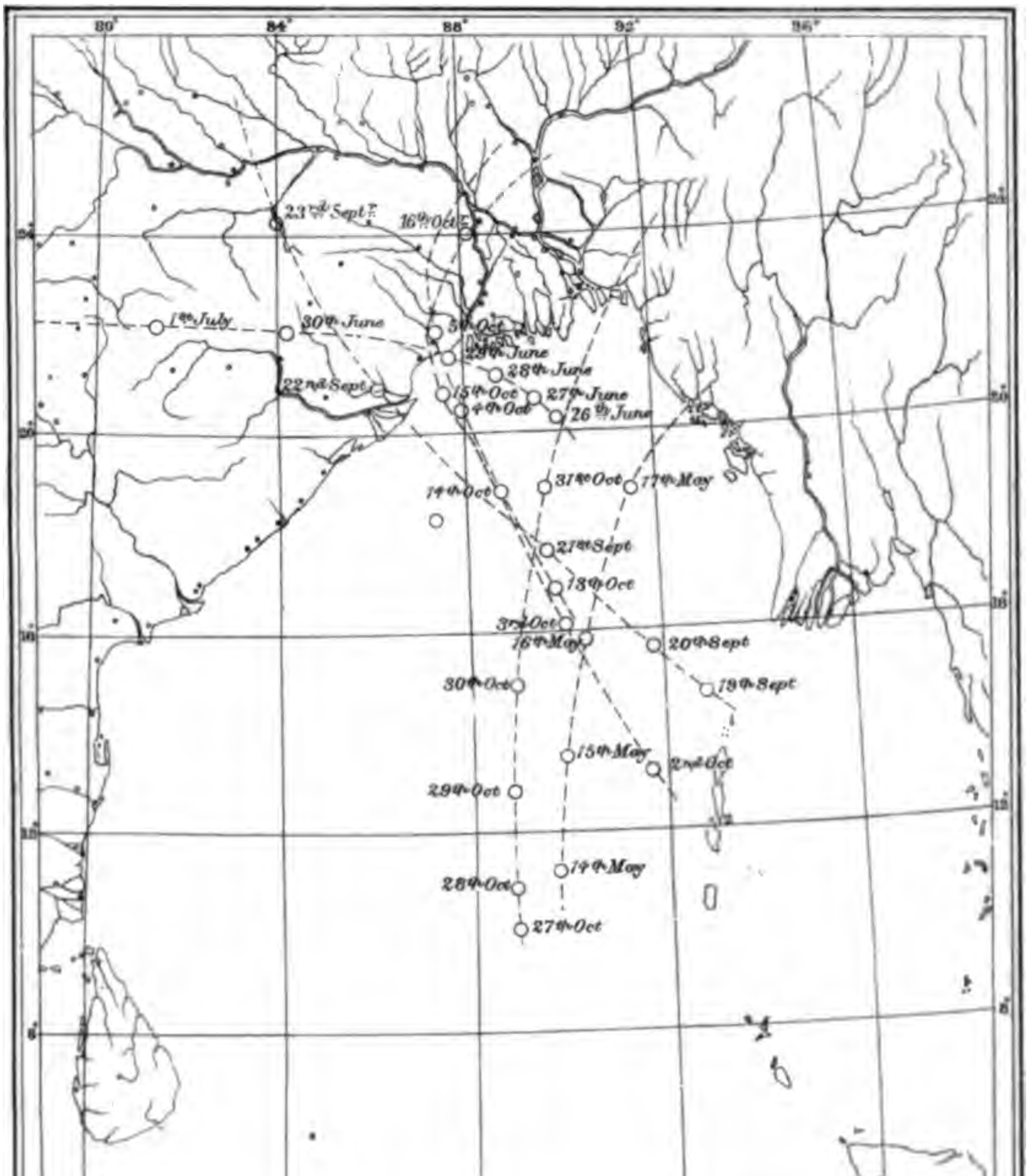


CHART SHOWING TRACKS OF THE SIX CYCLONES DESCRIBED IN CHAPTER III.



Reg No. 2945, Wr, I.—22-10-89.—600. Litho., S. I. O., Calcutta.